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IMPACT OF *SCALE-UP* ON  
SCIENCE TEACHING SELF-EFFICACY OF  
STUDENTS IN GENERAL EDUCATION SCIENCE COURSES

by

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A dissertation submitted in partial fulfillment of the requirements  
for the degree of Doctor of Education  
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## ABSTRACT

The objective of this study was to evaluate the effect of two pedagogical models used in general education science on non-majors' science teaching self-efficacy. Science teaching self-efficacy can be influenced by inquiry and cooperative learning, through cognitive mechanisms described by Bandura (1997). The Student Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) model of inquiry and cooperative learning incorporates cooperative learning and inquiry-guided learning in large enrollment combined lecture-laboratory classes (Oliver-Hoyo & Beichner, 2004). SCALE-UP was adopted by a small but rapidly growing public university in the southeastern United States in three undergraduate, general education science courses for non-science majors in the Fall 2006 and Spring 2007 semesters. Students in these courses were compared with students in three other general education science courses for non-science majors taught with the standard teaching model at the host university. The standard model combines lecture and laboratory in the same course, with smaller enrollments and utilizes cooperative learning.

Science teaching self-efficacy was measured using the Science Teaching Efficacy Belief Instrument – B (STEBI-B; Bleicher, 2004). A science teaching self-efficacy score was computed from the Personal Science Teaching Efficacy (PTSE) factor of the instrument. Using non-parametric statistics, no significant difference was found between teaching models, between genders, within models, among instructors, or among courses. The number of previous science courses was significantly correlated with PTSE score.

Student responses to open-ended questions indicated that students felt the larger enrollment in the SCALE-UP room reduced individual teacher attention but that the large round SCALE-UP tables promoted group interaction. Students responded positively to cooperative and hands-on activities, and would encourage inclusion of more such activities in all of the courses.

The large enrollment SCALE-UP model as implemented at the host university did not increase science teaching self-efficacy of non-science majors, as hypothesized. This was likely due to limited modification of standard cooperative activities according to the inquiry-guided SCALE-UP model. It was also found that larger SCALE-UP enrollments did not decrease science teaching self-efficacy when standard cooperative activities were used in the larger class.

This dissertation is dedicated to my late father, Lambert F. Kuhr, Jr.

We lost you before you could watch me graduate.

Now you have the best seat in the house.

## ACKNOWLEDGMENTS

No project can be completed alone. I would like to thank my committee, Drs. Bobby Jeanpierre, Cynthia Hutchinson, Robert Everett and Win Everham for their support and guidance throughout this research, and Dr. Diane Schmidt for her inspiration and for leading my cheering squad. My parents and children provided unwavering support and for this I am extremely grateful. Domo arigato gozaimashita to Deb Hanson Sensei for her meticulous editing. Finally, I am deeply indebted to Jeff Reach Sensei for helping me to learn the real power of self-efficacy.

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## TABLE OF CONTENTS

|  |      |
|--|------|
| LIST OF FIGURES .....                              | xi   |
| LIST OF TABLES .....                               | xii  |
| LIST OF ACRONYMS/ABBREVIATIONS .....               | xiii |
| CHAPTER ONE: INTRODUCTION .....                    | 1    |
| Conceptual framework.....                          | 2    |
| Research Setting .....                             | 3    |
| Research Problem .....                             | 4    |
| Design of the Study .....                          | 5    |
| Significance of the Study .....                    | 6    |
| Assumptions .....                                  | 7    |
| Limitations .....                                  | 8    |
| Definitions .....                                  | 8    |
| Organization of the Dissertation.....              | 10   |
| CHAPTER TWO: LITERATURE REVIEW .....               | 11   |
| Conceptual Framework.....                          | 13   |
| Self-efficacy .....                                | 13   |
| Self-efficacy as predictive of outcomes .....      | 14   |
| Active/inquiry learning and self-efficacy .....    | 15   |
| Cooperative learning and self-efficacy.....        | 17   |
| Influences and Outcomes of Related Constructs..... | 19   |
| Science attitudes.....                             | 20   |
| Science self-efficacy in higher education .....    | 21   |



|  |    |
|--|----|
| Cooperative learning, inquiry and science self-efficacy..... | 22 |
| Other influences on self-efficacy in science .....           | 25 |
| Self-efficacy in science teaching .....                      | 25 |
| Content mastery and science teaching self-efficacy.....      | 27 |
| Pedagogical mastery and science teaching self-efficacy ..... | 30 |
| Science teaching self-efficacy at the program level .....    | 31 |
| Self-image and science teaching self-efficacy .....          | 32 |
| SCALE-UP.....  | 34 |
| What is SCALE-UP .....                                       | 34 |
| Classroom design and student outcomes .....                  | 34 |
| Student outcomes with SCALE-UP .....                         | 37 |
| SCALE-UP in this study .....                                 | 38 |
| CHAPTER THREE: METHODS .....                                 | 39 |
| Research Design .....  | 39 |
| Comparison of teaching models.....                           | 40 |
| Variables.....   | 43 |
| Data Collection.....   | 44 |
| Population and sample selection .....                        | 44 |
| Assessment instrument .....                                  | 46 |
| Instrument validation.....                                   | 47 |
| Administration of the instrument .....                       | 49 |
| Data Analysis .....  | 51 |
| PTSE scores .....  | 52 |
| Open-ended questions .....                                   | 52 |

|   |    |
|---|----|
| CHAPTER FOUR: RESULTS .....                                     | 55 |
| Characteristics of the Population.....                          | 55 |
| Gender and major distribution .....                             | 55 |
| Withdrawal and pass/fail rates .....                            | 56 |
| PTSE Scores .....   | 58 |
| Research Questions.....   | 59 |
| Question 1.....   | 59 |
| Question 2.....   | 60 |
| Question 3.....   | 60 |
| Question 4.....   | 61 |
| Ancillary Analyses .....  | 62 |
| Differences among courses.....                                  | 63 |
| Differences among instructors .....                             | 63 |
| Differences between teaching models within a single course..... | 63 |
| Education majors .....  | 65 |
| Qualitative Findings .....                                      | 66 |
| Open-ended Question 1 .....                                     | 67 |
| Open-ended Question 2 .....                                     | 68 |
| Open-ended Question 3 .....                                     | 68 |
| Open-ended Question 4 .....                                     | 69 |
| Open-ended Question 5 .....                                     | 70 |
| Open-ended Question 6 .....                                     | 71 |
| CHAPTER FIVE: DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS ...   | 73 |
| Research Questions.....   | 73 |

|  |    |
|--|----|
| Question 1 .....   | 73 |
| Question 2 .....   | 76 |
| Question 3 .....   | 77 |
| Question 4 .....   | 79 |
| Qualitative Findings .....                               | 80 |
| Physical aspects .....                                   | 82 |
| Teacher attention .....                                  | 82 |
| Student group interaction .....                          | 83 |
| Course activities .....                                  | 84 |
| Conclusions .....  | 85 |
| Summary .....  | 86 |
| Recommendations .....                                    | 87 |
| APPENDIX A: ASSESSMENT INSTRUMENT .....                  | 89 |
| APPENDIX B: INTERNAL REVIEW BOARD APPROVAL LETTERS ..... | 92 |
| REFERENCES .....   | 95 |

## LIST OF FIGURES

|  |    |
|--|----|
| Figure 1: Conceptual diagram of the connection between SCALE-UP and science<br>teaching self-efficacy..... | 12 |
| Figure 2: Example standard model room.....   | 42 |
| Figure 3: Example SCALE-UP model room .....  | 43 |
| Figure 4: Withdrawal rates in each model, combined semesters .....   | 57 |
| Figure 5: Fail rates in each model, combined semesters .....   | 58 |
| Figure 6: Boxplots of PTSE scores in each model.....   | 59 |
| Figure 7: Boxplots of PTSE scores in each model, same course with the same instructor<br>.....             | 64 |

## LIST OF TABLES

|   |    |
|---|----|
| Table 1: Model and Section Enrollment by model, with number of sections.....            | 45 |
| Table 2: Reliability of the STEBI-B survey, previous and present studies .....          | 49 |
| Table 3: Return rates for surveys in the sample population, between models .....        | 50 |
| Table 4: Distribution of genders between models .....                                   | 55 |
| Table 5: Distribution of majors between models .....                                    | 56 |
| Table 6: Withdrawal and fail rates (n and %) by teaching model .....                    | 57 |
| Table 7: Correlation coefficients: PTSE with previous science courses in each model.... | 62 |
| Table 8: Response counts for open-ended questions in each model .....                   | 66 |
| Table 9: Topics for <i>Open-ended Question 1</i> in each model .....                    | 67 |
| Table 10: Topics for <i>Open-ended Question 2</i> in each model .....                   | 68 |
| Table 11: Topics for <i>Open-ended Question 3</i> in each model .....                   | 69 |
| Table 12: Topics for <i>Open-ended Question 4</i> in each model .....                   | 70 |
| Table 13: Topics for <i>Open-ended Question 5</i> in each model .....                   | 71 |
| Table 14: Topics for <i>Open-ended Question 6</i> in each model .....                   | 72 |

## LIST OF ACRONYMS/ABBREVIATIONS

|          |  |
|----------|--|
| NCSU     | North Carolina State University  |
| NRC      | National Research Council  |
| PSTE     | Personal Science Teaching Efficacy   |
| SCALE-UP | Student-Centered Activities for Large Enrollment Undergraduate<br>Programs |
| STEBI-B  | Science Teaching Self-efficacy Belief Instrument-B                         |
| STOE     | Science Teaching Outcome Expectancy  |

## CHAPTER ONE: INTRODUCTION

The competing pressures of large-scale efficiency and small group learning present faculty and administration with difficult choices between the economics of scale and best-practice pedagogy. The resolution of these competing pressures in higher education will have far-reaching effects on the goal of achieving science literacy for all Americans (Rutherford & Ahlgren, 1990). In order to reach this goal, the National Research Council (NRC) outlined a program which advocates inquiry and collaborative learning pedagogy in science courses at all levels (NRC, 1996). Elementary education teachers are a key component of the program because it is in the elementary classroom that many students first encounter science. Yet elementary teachers learn science in ways that may not be conducive to either their science learning or their science teaching.

In many undergraduate programs, elementary education majors learn foundational science in general education science content courses for non-science majors. These courses are content-driven and are frequently characterized by large enrollment sections with a mix of majors. Assessment is generally content-based, with little attention paid to affective measures of science confidence or anxiety. However, the ability to teach science requires both confidence that one understands the content, and confidence in one's ability to convey that content. Indeed, whether, when, and how teachers teach science can be predicted by their level of science teaching confidence (self-efficacy) (Ashton, 1985).

### Conceptual framework

Science courses utilizing pedagogical models that espouse inquiry and collaborative/cooperative learning were postulated to increase science teaching self-efficacy. Classroom strategies that incorporate inquiry and cooperative learning can contribute to self-efficacy through inputs proposed by Bandura (1977). Self-efficacy is defined as confidence in ability to achieve a goal, and the four inputs that lead to self-efficacy are: mastery learning, vicarious experience, verbal persuasion and emotional state. Input from each of these four sources, processed cognitively, results in a domain-specific level of self-efficacy. Of the four, enactive mastery learning is the most influential, and for it to enhance self-efficacy the experience must be challenging and require perseverance (Bandura, 1997), conditions that are met in inquiry learning. In inquiry learning students learn by posing questions, investigating phenomena, gathering and analyzing data, proposing answers and testing those answers (NRC, 1996; Lee, Green, Odum, Schechter & Slatta, 2004). Similarly, cooperative learning provides input to the social factors of Bandura's self-efficacy theory. Social interaction in cooperative/collaborative learning enables students to observe and compare peer behaviors (vicarious experience), and give and receive support (verbal persuasion) as they work to achieve common goals (Johnson, Johnson & Smith, 1998).

Classroom design features can encourage or inhibit social interactions (Strange & Banning, 2001) and support or detract from cooperative learning. Classroom designs with fixed seating, such as lecture halls, carry emotional messages of authority, formality, and reduced peer interaction (Bligh, 2000). Conversely, flexible seating arrangements with chairs, tables, and public presentation spaces foster discussion and collaboration (Cornell,



2002). Thus, a learning space that is designed to support cooperative learning and encourage peer interaction has the potential to enhance the self-efficacy gains of cooperative learning.

### Research Setting

Small-group collaboration and inquiry pedagogy are difficult to implement in large enrollment general education science courses, challenging the reforms advocated by the NRC (1996). One of the models designed to meet this challenge was the Student Centered Activities for Large Enrollment Undergraduate Programs project (SCALE-UP; Beichner & Saul, 2004) at North Carolina State University (NCSU). This model utilized “inquiry-guided learning” (Lee, et al., 2004, p.9) in a cooperative/collaborative learning environment, with physical modifications of the classroom that supported small groups within large enrollment sections. The model was initially developed for physics at NCSU and later expanded to other majors science courses.

At a small but rapidly growing public liberal arts university in the southeastern United States, several science classrooms were modified according to the SCALE-UP model while others were left unchanged. The standard model of science teaching at this institution utilizes a pedagogical philosophy that integrates laboratory investigation activities with lecture/classroom activities in small classes, and promotes cooperative learning as one of its guiding principles (*Introduction to the University*, 2007). The SCALE-UP model was adopted as a means of implementing this philosophy in a large enrollment format. Faculty utilizing the SCALE-UP rooms attended seminars on inquiry, cooperative/collaborative learning and use of the modified rooms. Beginning with the

Fall 2006 semester, the modified rooms were used for both science majors courses and general education science courses for non-science majors.

### Research Problem

The SCALE-UP model incorporated a specific room design in which inquiry and cooperative/collaborative pedagogy took place, and had the potential to influence the four factors that determine self-efficacy. The impact of this model on science teaching self-efficacy of non-science majors in general education science courses was investigated in this research project.

*Question 1:* Was there a difference in the level of science teaching self-efficacy between students in the SCALE-UP courses and standard small enrollment courses?

*Hypothesis 1:* The SCALE-UP model would have a positive effect on science teaching self-efficacy of non-science majors, compared to the standard model.

*Question 2:* Was there a difference among majors in the level of science teaching self-efficacy overall and within each model (SCALE-UP vs. standard small sections)?

*Hypothesis 2a:* There would be a difference among majors in science teaching self-efficacy overall.

*Hypothesis 2b:* The SCALE-UP model would reduce the relative difference in science teaching self-efficacy among majors in comparison to the standard small enrollment model.

*Question 3:* Was there a difference between males and females in the level of science teaching self-efficacy overall and within each model?

*Hypothesis 3a:* Males would exhibit higher levels of science teaching self-efficacy than females overall.

*Hypothesis 3b:* The SCALE-UP model would reduce the relative difference in science teaching self-efficacy between females and males in comparison to the standard small enrollment model.

*Question 4:* Did the number of previous science classes affect the level of science teaching self-efficacy overall and within each design?

*Hypothesis 4a:* Overall, students with more previous science classes would have higher science teaching self-efficacy than students with fewer previous science classes.

*Hypothesis 4b:* The SCALE-UP model would reduce the relative difference in science teaching self-efficacy among students with more and fewer previous science classes in comparison to the standard small enrollment model.

### Design of the Study

The study design used a quasi-experimental nested 2x2 factorial design. Both instructional model and gender were independent variables, with two levels each, and science teaching self-efficacy was the dependent variable. Multiple course sections and disciplines were nested within each treatment. Students in general education science courses taught with each model (SCALE-UP vs. standard) were assessed for science teaching self-efficacy. Course discipline differed between models, as did faculty and syllabus. Gender and number of previous science courses were recorded, as well as

responses to open-ended questions related to student experience and perceptions of course activities and room design.

Self efficacy in science teaching was measured using the Science Teaching Belief Instrument-B (STEBI-B; Enochs & Riggs, 1990; Bleicher, 2004), a 23 item Likert-style questionnaire with a five point response scale (Appendix A). The survey parses into two factors, Personal Science Teaching Efficacy (PTSE) and Science Teaching Outcome Expectancy (STOE). The entire instrument was administered, however, only items measuring PTSE were used to calculate a PTSE score for use in this research. PTSE measured confidence in one's ability to teach science, the factor of interest in this study, whereas STOE measured the belief that elementary students will learn as a result of one's teaching. STOE items related to factors that could influence elementary student learning, which were not addressed in this study. Open-ended questions were appended to the survey instrument to enrich the numerical findings (Appendix A). Retention and pass/fail rates were obtained from the host university as relevant data for institutional use.

The instrument was administered in the Fall 2006 and Spring 2007 semesters. All general education science courses taught with the SCALE-UP model were selected for evaluation, and sufficient numbers of standard model daytime general education science sections were selected to provide an approximately equal number of students. Different general education science disciplines were taught in each kind of room; only one standard model section had the same discipline course as a SCALE-UP model section.

### Significance of the Study

This study of the effect of the SCALE-UP model on science teaching self-efficacy of non-science majors contributed to the research base in the following ways:

1. It measured the impact of the large enrollment SCALE-UP model on science teaching self-efficacy of non-science majors compared to the smaller standard model in general education science courses.
2. It added to the research base on self-efficacy in science teaching of elementary education majors by evaluating the effect of the large enrollment SCALE-UP model compared to the small enrollment standard model
3. It provided insight into the use of the STEBI-B as a measure of science teaching self-efficacy for non-elementary education non-science majors, and established a base upon which to modify the instrument in order to better address science self-efficacy as a course outcome for this population.
4. In concert with other research, it may assist the host university in determining the educational value of the SCALE-UP room design for large enrollment courses prior to investing in modifications of other classroom and laboratory spaces.

#### Assumptions

It was assumed that students answered the questions on the assessment instrument truthfully. It was also assumed that non-elementary education majors were able to consider themselves as elementary teachers as they answered the questions. It was further assumed that the assessment instrument used, the STEBI-B (Enochs & Riggs, 1990; Bleicher, 2004), measured science teaching self-efficacy of non-elementary education majors with the same degree of accuracy as for elementary education majors.

### Limitations

Although this study may serve to support implementation of the SCALE-UP model at other institutions, the results of the study are limited to the general education student population at the host university. Science teaching self-efficacy results obtained for non-science majors cannot be extrapolated to science majors, or to general education students at other institutions. The latter is due to the pedagogical practices at the host institution which utilized cooperative learning in small studio-style combined lecture/laboratory sections. These practices affect mastery learning, which is a strong factor in the development of self-efficacy (Bandura, 1997) regardless of the teaching model used.

### Definitions

*Active learning:* An active learning environment is one “that engages students in the learning process....requiring students to do meaningful learning activities and think about what they are doing” (Prince, 2004, p. 223). Active learning includes, but is not limited to cooperative/collaborative learning, inquiry learning, problem based learning, and various classroom learning strategies such as jigsawing, brainstorming and minute papers. Extensive lecture is not included in most definitions of active learning (Paulson & Faust, n.d.).

*Cooperative/collaborative learning:* “the instructional use of small groups so that students work together to maximize their own and each other’s learning” (Johnson, Johnson & Smith, 2006, p.1:12). This contrasts with individualistic learning where each student’s activity has no bearing on other student’s learning, and competitive learning where the achievement of one student’s goals is at the

expense of another student's goals (Johnson, et al., 2006). While some researchers distinguish between cooperative and collaborative learning, these terms are used interchangeably in this dissertation, due to extensive cross-use of these terms in the literature.

*Inquiry learning:* A form of active learning in which student learning takes place through activities that involve making observations, asking questions, collecting and analyzing data, proposing answers and testing the proposed answers (NRC, 1996).

*Inquiry-guided learning:* A form of active learning defined by North Carolina State University as “an array of classroom practices that promote student learning through guided and, increasingly, independent investigation of complex questions and problems, often for which there is no single answer” (Lee, et. al, 2004, p.9). It includes a variety of active learning classroom strategies and techniques (Lee, et. al, 2004).

*SCALE-UP model:* A pedagogical model that incorporates inquiry-guided and cooperative/collaborative learning in a supportive physical environment designed to house large student enrollments (Beichner and Saul, 2004). The room design at NCSU houses 99 students; at the host university SCALE-UP rooms housed 81 students at nine large round tables accommodating nine students each, seated on desk-type moveable chairs.

*Science teaching self-efficacy:* Used herein as a measure of self-confidence in one's ability to teach or explain a science topic at the elementary school level, as measured by the STEBI-B (Enochs & Riggs, 1990; Bleicher, 2004).

*Self-efficacy in science, science self-efficacy:* A measure of self-confidence in one's ability to understand science.

*Standard model/standard room:* At the host university, a studio-style science room containing both fixed laboratory bench/table space and desk/student seating, with a student enrollment capped at 35. The standard teaching model combined lecture and laboratory sections into a single course, with an emphasis on cooperative learning.

*STEBI-B:* Science Teaching Efficacy Belief Instrument-B; a 5-point Likert-style survey assessment instrument developed and validated by Enochs and Riggs (1990) to measure self-efficacy in science teaching of pre-service elementary education students. The STEBI-B was modified and revalidated by Bleicher (2004); the modified version was used in this research.

### Organization of the Dissertation

Chapter 1 of this dissertation lays the framework for the research described in subsequent chapters. The conceptual framework, hypotheses, and a brief outline of the research design are described, as well as limitations of the work, and definitions. Previous work relevant to the research herein are reviewed and critiqued in Chapter 2. The review and critique provide the foundation upon which the present study was constructed. Chapter 3 provides a detailed description of the methods used in the research, including validation and reliability analysis of the assessment instrument. Research results, with tables and figures summarizing the data, are contained in Chapter 4. Chapter 5 discusses the research results, implications of the study, and recommendations for further work.



## CHAPTER TWO: LITERATURE REVIEW

Science teaching self-efficacy is a narrow construct that has been predominately evaluated in pre-service and in-service teachers. This study evaluated this construct in a larger, more diverse population, within the framework of cooperative and inquiry learning. Consequently, exploration of the literature in several areas is necessary. The conceptual diagram presented in Figure 1 is the organizing framework for the literature review.

The review begins by laying the foundation for the concept of self-efficacy, and the factors important to the development of self-efficacy. The impact of cooperative learning and active/inquiry learning on self-efficacy are then explored. Due to the narrowness of the construct of science teaching self-efficacy, and the diverse population in this study, an exploration of related broader constructs is warranted. Science attitude and science self-efficacy are explored for relevant influences and outcomes, including the impacts of cooperative learning and active/inquiry learning on these constructs. The literature on science teaching self-efficacy is then examined, including components, influences, populations, assessments, and outcomes. The final section describes the SCALE-UP model, research on classroom design, and outcomes using the SCALE-UP model.

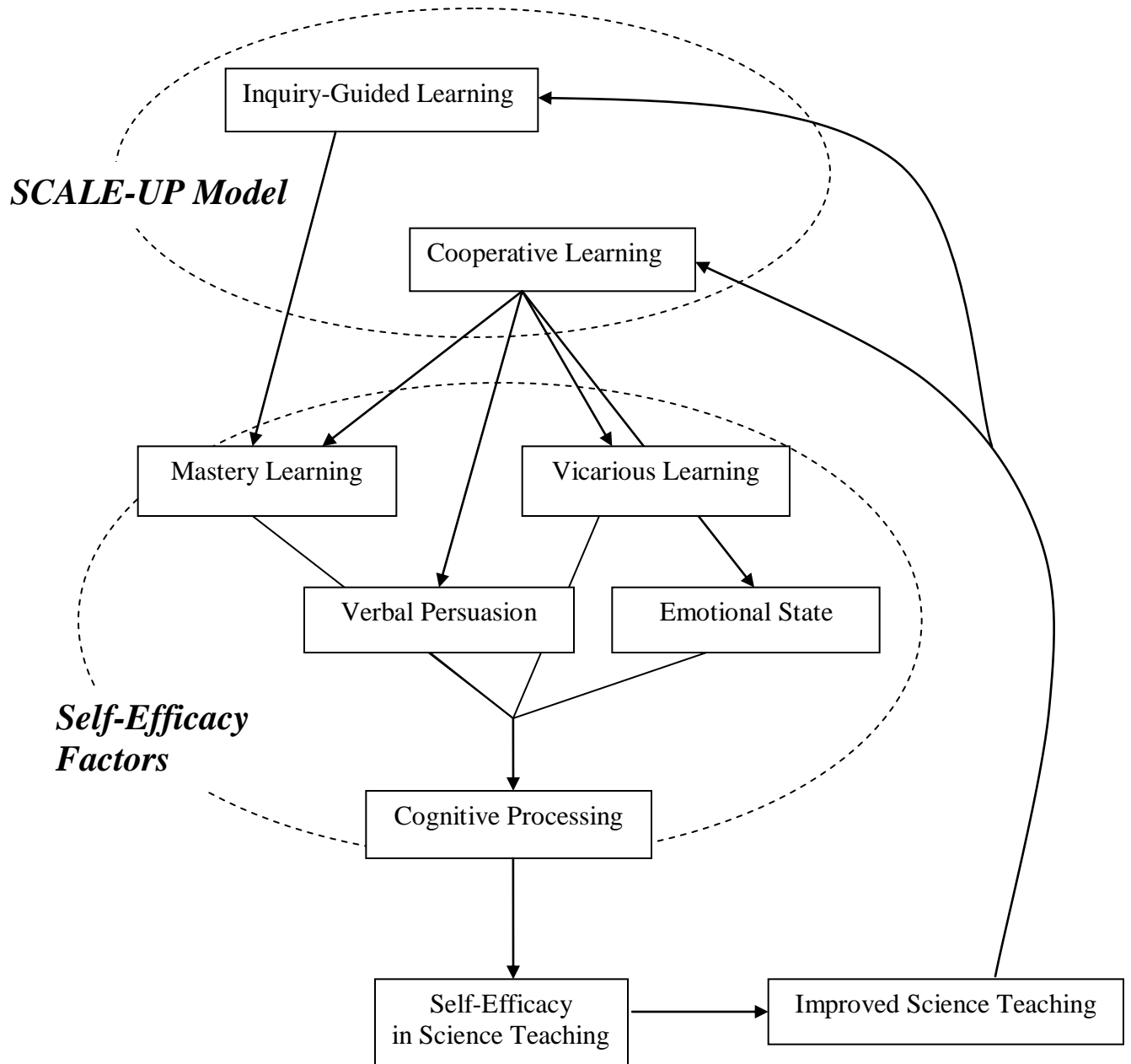


Figure 1: Conceptual diagram of the connection between SCALE-UP and science teaching self-efficacy

### Conceptual Framework

The conceptual framework presented here and illustrated in Figure 1 assembles the cognitive and affective effects of inquiry and cooperative learning, and applies it to science teaching self-efficacy in a population of non-science majors, including pre-service elementary teachers. Science teaching self-efficacy is the focus of many scholars interested in improving science methods courses, but little work on science teaching self-efficacy has been done in foundational science courses for preservice elementary teachers. Preservice elementary teachers gain much of their science content in these foundational courses. Inquiry and collaborative learning were hypothesized to positively impact science teaching self-efficacy of non-science major students, thus potentially improving the quality of science teaching in the elementary grades.

### Self-efficacy

To perform an action in order to achieve a goal, one must have both the belief that the goal is attainable and that one has the ability to achieve it. Self-efficacy relates to “the interaction between person and task” (Vrugt, Langereis, & Hoogstraten, 1997, p. 61) and is domain-specific (Bandura, 1997). As Bandura describes it, “perceived self-efficacy refers to beliefs in one’s capabilities to organize and execute the courses of action required to produce given attainments” (p.3).

Bandura (1997) posits four sources of information for the development of self-efficacy. These are:

enactive mastery experiences that serve as indicators of capability; vicarious experiences that alter efficacy beliefs through transmission of competencies and comparison with the attainments of others; verbal persuasion and allied types of

social influences that one possesses certain capabilities; and physiological and affective states from which people partly judge their capableness, strength, and vulnerability to dysfunction (p. 79).

These four inputs must be cognitively processed before any gains in self-efficacy can be realized. Not only does one need to have the experience and reinforcement of achieving the performance goal, but one must also recognize that the achievement has taken place due to one's efforts, and incorporate it into estimates of ability.

Mastery experience, or performance accomplishment, is the dominant contributor to the development of self-efficacy. Successful performances raise self-efficacy and multiple successful experiences buffer self-efficacy against the occasional failure. While self-efficacy is considered domain-specific, attainment of a specific action can be generalized in limited ways to similar actions (Bandura, 1977). Additional mastery tasks must be incrementally challenging so that effort is required to accomplish the goal, and the achievement of that goal must be attributed to personal skill or effort, rather than outside influences, such as luck (Bandura, 1997.)

#### *Self-efficacy as predictive of outcomes*

Self-efficacy has been shown to be predictive of academic performance in multiple studies. In a meta-analysis of 36 studies during the ten year period following Bandura's (1977) introduction of self-efficacy theory, Multon, Brown and Lent (1991) found a statistically significant positive relationship between self-efficacy beliefs and academic performance in populations that included all school ages from elementary to college, and in average as well as low-achieving students. In college students, a later meta-analysis of 109 studies conducted between 1981 and 2002 found self-efficacy to be

the best predictor of college GPA (Robbins, Lauver, Davis, Langley & Carlstrom, 2004). In undergraduates, self-efficacy was found to be predictive of college performance and adjustment (Chemers, Hu & Garcia, 2001); mathematics grades and intention to enroll in mathematics courses (Lent, Lopez & Bieschke, 1993); and selection of college major/career choice (Luzzo, Hasper, Albert, Bibby & Martinelli, 1999).

The connection between self-efficacy and academic performance is mediated by mastery goals and deep cognitive processing, according to the model developed by Fenollar, Roman and Cuestas (2007). In this study of 553 diverse undergraduates, questionnaire data on achievement goals, study strategies, self-efficacy and class size were subjected to structural equation modeling. Self-efficacy was found to significantly affect both mastery achievement goals and deep processing study strategies. Mastery goals have a significant direct effect on deep processing, which in turn significantly affects academic performance. Class size had a significant negative direct effect on academic achievement. A study conducted in high school students found similar results (Greene, Miller, Crowson, Duke & Akey, 2004). These results suggest that efforts to improve self efficacy, such as mastery and vicarious learning, and social comparison, lead to higher performance outcomes through goal and processing strategies.

#### *Active/inquiry learning and self-efficacy*

Active learning strategies, including inquiry learning, provide performance feedback through participation in the activity. Active learning strategies are common in K-12 settings and gaining increasing use in higher education; while inquiry strategies are relatively new, especially in higher education (Pasley, Weiss, Shimakus & Smith, 2004; Walczyk & Ramey, 2003). Active learning requires students to participate in the learning

process, as compared to being passive recipients. Classroom strategies for active learning, such as jigsawing, think-pair-share, laboratory investigation, minute papers, etc., serve as ways for students to process and consolidate knowledge (Benjamin, 1991; Paulson & Faust, n.d.). Active learning strategies were found to enhance attitudes toward science, science and science-teaching self-efficacy, and academic achievement in a number of studies (Leonard, 2000; Prince, 2004; Wilke, 2003).

Inquiry learning, as a form of active learning, involves students in the process of discovery and is inductive in nature. Classroom inquiry strategies include case-based learning, problem-based learning and open-ended investigations (Prince & Felder, 2006). These strategies parallel the scientific process in that the outcomes are not known, the process may need to be invented, new knowledge is constructed and built on prior knowledge, and new questions are generated which lead to new investigations (NRC, 2000). Successful performance leads to mastery, and thus to improvement in self-efficacy (Bell, 2001; Bryant, 2006; Prince & Felder, 2007; Wallace, Tsoi, Calkin & Darley, 2003; Weld & Funk, 2005; White, 1998; Wilkinson, 2004).

Cognitive processing is an essential element of self-efficacy (Bandura, 1997). Reflective journaling provides students with an awareness of their own learning process and progress. Programs that included reflective writing along with active learning saw greater gains in outcomes related to science attitudes and academic achievement (Bell, 2001; White, 1998) confirming that processing of the mastery gain is necessary in order for changes in self-efficacy to take place (Bandura, 1977).

### *Cooperative learning and self-efficacy*

Mastery experience is only one of the four inputs to self-efficacy, according to Bandura's theory (1997). Vicarious experience, verbal persuasion and emotional state also contribute to the development of self-efficacy through reinforcement or degradation of self-efficacy beliefs established by mastery learning. Vicarious experience and verbal persuasion are interpersonal social inputs. Vicarious experience establishes models and yardsticks by which to judge the quality of one's performance. Important elements of vicarious experience include the similarity and expertness of the model, and the difficulty of the task being modeled. In a classroom setting, models may be peers, instructors, or external models, such as videos or guest speakers. Verbal persuasion from peers, teachers, and others supports and reinforces one's belief in ability by external confirmation of that belief, but only if the reinforcement is positive, authentic, and realistic. The source of the verbal appraisal must be both knowledgeable and credible in the domain area for it to contribute to self-efficacy. The final input to the development of self-efficacy is emotional state. Feelings of anxiety, dread, and fear detract from self-efficacy, whereas positive feelings contribute to and reinforce self-efficacy (Bandura, 1997).

Cooperative learning as an instructional strategy has been shown to improve performance outcomes in multiple studies (Bowen, 2000; Johnson, et al., 2006; Shibley & Zimmaro, 2002). Cooperative and collaborative learning contribute to self-efficacy through the patterns of interaction that occur in groups. Cooperative groups promote positive interactions in the following ways (Johnson et al., 2006):

1. Giving and receiving help and assistance...
2. Exchanging resources and information...
3. Giving and receiving feedback on taskwork and teamwork behaviors...
4. Challenging each other's reasoning...
5. Advocating increased efforts to achieve...
6. Mutually influencing each other's reasoning and behavior...
7. Engaging in interpersonal and small group skills...
8. Processing how effectively group members are working together...(p.A:15)

These interactions carry input information for self-efficacy through vicarious experience, verbal persuasion, and positive emotional state. Cooperative learning may also contribute to personal self-efficacy through collective efficacy. Collective efficacy is a property that emerges at the group level, but the perception of collective efficacy resides in each of the group members. The outcomes of the group process may affect and be affected by individual's perceived efficacy of the group, and is affected by the degree of interdependence of the group (Bandura, 2000).

In a study of 600 introductory chemistry college students, cooperative learning with a higher degree of interdependence improved retention and performance compared to unstructured cooperative learning and didactic instruction (Dougherty, Bowen, Berger, Rees, et. al, 1995). A case study of 60 upper division college psychology students (Bryant, 1978) established a cooperative goal structure in which final grades were awarded based primarily on group performance. Qualitative findings included student reports of increased freedom to disagree and/or be wrong without judgment in the group, fostering discussion and debate; positive emotional environment; "realizing that they had



more talents than they thought they had” (p. 184); and development of interpersonal group skills.

Social comparison is also part of group function, and is important to the development of self-efficacy (Bandura, 1997). In high school students, social comparison was found to be important to the development of self-efficacy in mathematics (Pietsch, Walker & Chapman, 2003). Pintrich and DeGroot, (1990) determined that external social comparison was more important to perceptions of self-regulated learning than internal comparisons. Self-regulated learning is an essential component of the metacognitive processing necessary for the establishment of self-efficacy (Bandura, 1997). Thus, cooperative learning may contribute to self-efficacy through collective efficacy, social comparison, and positive interpersonal interactions.

While it may be possible to implement active learning in the classroom without cooperative learning, it is nearly impossible to implement cooperative learning without some form of active learning. Combining cooperative learning with active learning, particularly if the active learning is structured as inquiry, can enhance self- efficacy through all four pathways of information: enactive mastery experience, vicarious experience (peer comparison), verbal persuasion, and positive emotional state.

#### Influences and Outcomes of Related Constructs

Factors which may influence science attitudes and science self-efficacy may also influence science teaching self-efficacy. Student attitudes about science are not the same as self-efficacy in science, although attitudes such as self-esteem, enjoyment, and fear of failure can contribute to or derive from self-efficacy (Bandura, 1997). Likewise, science self-efficacy is not the same as science teaching self-efficacy, yet factors that influence

science self-efficacy may also impact science teaching self-efficacy. These related constructs are explored in this section.

### *Science attitudes*

In a review of the literature on attitudes toward science (primarily K-12), Osborne, Simon, and Collins (2003) found that the concept of “attitude toward science” was multidimensional, and included attitudes toward the teacher, attitudes toward the content, motivation, self-esteem in content area, enjoyment of science, attitudes of parents, peers and friends, nature of the classroom environment, and fear of failure in the course, among others. In a subset of studies that were more focused, Osborne, et al. found that: gender influences attitudes toward science, with boys having more positive attitudes; higher levels of involvement and connection with teachers and peers in the classroom positively affect science attitudes; and, how science is taught affects attitudes, with confident teachers using a variety of classroom methods having positive effects on students’ attitudes toward science. The reviewers held that student involvement in the learning process is key to developing positive attitudes, and recommended focused studies of teacher variables to determine the important factors that determine student attitudes.

Science attitude studies of higher education non-science majors, while not focused directly on self-efficacy, may contain scales relating to the measurement of self-efficacy. For example, in comparing science majors and non-science majors, Gogolin and Swartz (1992) used the Attitude Toward Science Inventory (ATSI). This instrument includes scales for anxiety toward science, self-concept in science, and enjoyment of science, all of which may be related to self-efficacy in science. Using pre- and post-test

ATSI scores, attitudes of students in general education human anatomy and physiology were compared to attitudes of students in the second semester of freshman biology. Non-science majors had lowered anxiety levels after the course than before, and better attitudes toward science. Interviews conducted with non-science majors in the study found that peer groups were an important influence on science attitudes, and that previous science experiences in K-12 were important in shaping attitudes and motivation. The authors suggested that non-science majors would respond better to teachers who are more “person oriented” in order to reduce anxiety levels and improve attitudes, whereas science majors respond better to “subject-oriented” teachers who challenge them intellectually. The authors felt that increasing students’ confidence in their ability to learn was an important objective in science education.

#### *Science self-efficacy in higher education*

In higher education, self-efficacy in science majors has been found to predict achievement, persistence and career interest. In a study of chemistry students, self-efficacy levels in chemistry predicted final course performance, even when previous achievement in other courses was controlled (Zusho, Pintrich, and Coppola, 2003). In another study, freshmen and sophomores in a science and engineering career planning course were assessed to determine the contribution of self-efficacy, interest congruence and consequence thinking on grades and persistence in science/technical majors. Two self-efficacy instruments developed by the authors were used in this study: the Self-Efficacy for Technical/Scientific Fields-Educational Requirements, and Self-Efficacy for Academic Milestones. The first instrument measured confidence to complete academic requirements for the chosen major and the second measured confidence to achieve certain

milestones outside the major but critical to the success of the field. Self-efficacy was found to be the most important predictor of both academic achievement and career prediction in this group (Lent, Brown, and Larkin, 1987).

*Cooperative learning, inquiry and science self-efficacy*

According to Bandura (1977), peer interaction influences self-efficacy through reinforcement, social support and comparison. Research in teaching and learning has demonstrated the effectiveness of learning in cooperative group settings, compared with individualistic competitive settings and with group settings where assignments are parceled out for completion with little or no interaction between members. Cooperative groups exhibit positive interdependence, frequent and positive face-to-face interpersonal interaction, individual accountability for group goals, and regular processing of group function and progress toward group goals (Johnson and Johnson, 1994).

Multiple methods of cooperative group learning have been developed. A meta-analysis of cooperative learning methods (Johnson & Johnson, 2002) found that eight diverse methods had significant impact on student achievement. These methods ranged from jigsawing to group investigations. The effectiveness of cooperative learning is due, according to the authors, to its roots in developmental and social cognition, and beneficial impacts range from reducing racism and antisocial behavior to increasing achievement, motivation and self-efficacy. Gilbert (1995) found that dividing large university classes into smaller cooperative groups, increasing student/instructor interaction, using active learning strategies, and focusing on inquiry and investigation promoted higher achievement. Similarly, Leonard's (2000) evaluation of teaching styles also recommended collaborative constructivist learning for college science instruction.

Students' ideas about the nature of science may be influenced by their beliefs about the nature of knowledge, according to a phenomenological study of five students conducted by Wallace et al. (2003). They found that a constructivist inquiry biology course improved student understanding of the role of experiment in biology and that students with "constructivist learning beliefs" gained greater conceptual understanding than those with "positivist learning beliefs."

In a large-enrollment study of biology students, Ebert-May, Brewer, and Allred (1997) found that combining cooperative learning with constructivist, inquiry-based activities led to more participation, better understanding of the nature of science, and improved self-efficacy in "doing science, analyzing data, and explaining biology to other students" (p.604) than did traditional biology lecture and laboratory activities. This research took place with lecture classes of 140 students and 25-30 students in laboratory sections. Similar strategies were incorporated into a larger lecture section of 450 students, with similar results. The authors used a self-constructed assessment of science self-efficacy, and used nationally-available assessments of biology knowledge. In this study, no achievement difference on the national assessment instrument was observed between experimental (cooperative) and traditional (lecture) sections, in contrast to other research (see for example, Johnson & Johnson, 1994). However, the study by Ebert-May, et al. does indicate that cooperative inquiry learning can take place in large-enrollment sections without loss of content knowledge.

Implementation of cooperative/inquiry leaning activities can be problematic and requires attention to several factors. Liang and Gabel's (2005) study used six sections of an introductory chemistry course for elementary education majors. Three were taught

with a cooperative inquiry model implemented only during the last four weeks of the semester, and three sections continued as traditional lecture/small cooperative group model. Students were tested for conceptual knowledge, surveyed for attitude using the Chemistry Attitude Survey, and selected groups were interviewed. No significant differences were noted between treatments on either achievement or attitude tests; however an interaction effect was noted between instructor and students in one of the traditional sections, which may have affected the results. Students reported a more supportive and interactive learning environment in the inquiry classes, and interviewees reported more interdependent cooperation in the inquiry sections as opposed to a divide-and-conquer strategy in the traditional sections. Problems with this study include the implementation of the intervention at the end of the semester, when students have been accustomed to the traditional format; at the time of implementation student concerns for grades were high; and the differential ability of instructors to adapt their traditional teaching methods to the new format.

A pilot interactive integrated lecture/laboratory program for elementary education majors described by Guziec and Lawson (2004) implemented active learning and training in science methods in four areas: biology, chemistry, physics and geology. Students learned science content with methods they would be able to use in their own classrooms. A majority of students reported increased interest in science following the course, lending support to the benefits of both active learning and a breadth of content knowledge in this population. Unfortunately, achievement gains could not be measured due to problems with the assessment instruments used.

### *Other influences on self-efficacy in science*

Both gender and number of previous science courses have been found to affect self-efficacy in science and may influence the results of any study of science or science teaching self-efficacy. In numerous studies, in all school age groups, males report higher levels of interest in science and self-efficacy in science (DeBacker & Nelson, 2000; Lupart, Cannon & Telfer, 2004; Miller, Blessing & Schwartz, 2006; Neathery, 1999; Osborne, et al., 2003; Pajares, 2002; Stark, 1999; Weinburgh, 1995). Smist et al. (1994) reported that although high school males and females had equal attitudes toward science, females were less likely to be interested in a career in science. Reports of females' lower self-efficacy in science, and less interest in science, is an issue of concern for the female-dominated elementary teaching profession in whose classrooms early and critical exposure to science occurs.

In addition to gender effects, students with greater numbers of previous science courses report higher levels of science interest, greater science self-efficacy and greater science teaching self-efficacy in a number of studies of science majors, non-majors and tellingly, pre-service elementary education majors (Jarrett, 1999; Joseph, 2003; Kumar & Morris, 2005; Ramey 1998; Wenner, 2001).

### Self-efficacy in science teaching

The structure of the learning experience is particularly critical in elementary grades when children's sense of self-efficacy is fragile and still forming (Bandura, 1997). Using Bandura's four pathways to the development of self-efficacy, teachers can contribute to the development of self-efficacy in their students by constructing learning experiences that provide opportunities for mastery experience; provide comparative

performance information; provide authentic reinforcement; and ensure that these opportunities are exciting but not stressful. Because it is easier to degrade high efficacy beliefs than it is to improve low efficacy beliefs (Bandura, 1997), it is important to have efficacy-building experiences occur early and often in children. However, research has found that teachers will spend less time on teaching topics in which they themselves have weak self-efficacy (Bandura, 1997; Pintrich and Schunk, 2002). Therefore, improving science teaching self-efficacy in elementary education majors should be of special concern in higher education. It is in the future classrooms of these students that children will have their earliest experiences with science.

Elementary education teachers must perform the task of science teaching, therefore the narrower construct of self-efficacy in science teaching is of greater import than the broader concept of science self-efficacy. Tests of self-efficacy that are specific to the domain task (such as science teaching self-efficacy) are more predictive of related outcomes than tests that measure more global outcomes (such as science self-efficacy) (Pajares, 1996). Bandura (1997) described two expectations that determine behavior based on self-efficacy: personal efficacy (can I perform the action?) and outcome efficacy (will my action produce the desired effect?). Using a Teacher Efficacy Scale, Gibson and Dembo (1984) confirmed that there are two dimensions to teacher efficacy: a personal belief that “one has the skills and abilities to bring about student learning” (p.573) and a belief that the desired outcome will actually occur, recognizing that student learning may be affected by factors external to personal teaching skills and abilities. Enochs and Riggs (1990) developed the Science Teacher Efficacy Belief Instrument (STEBI-B) to measure these two dimensions in pre-service elementary teachers teaching science. The STEBI-B



has been widely used to evaluate the effectiveness of teacher education programs (Joseph, 2003; Morrell & Carroll, 2003; Tschannen-Moran, Hoy & Hoy, 1998) and was the instrument used in this study.

Palmer (2006) proposed that elementary teachers teaching science must have both content mastery and pedagogical mastery in order to develop self-efficacy in science teaching, and that imagining oneself teaching science was an important component. Pre-service elementary students were surveyed quantitatively before and after a science methods course using the STEBI-B to determine science teaching self-efficacy; the same students were surveyed qualitatively during the course using open-ended questions to determine the effect of a lecture, a hands-on workshop and a reflective exercise on content and pedagogical mastery and self-image. Pedagogical mastery was found to have the greatest impact on science teaching self-efficacy, followed by positive teaching self-image and content mastery, although Palmer argues that content mastery is as necessary to effective teaching as is pedagogical mastery.

#### *Content mastery and science teaching self-efficacy*

Fewer than three in ten elementary teachers report feeling well qualified to teach elementary science and seven in ten would like more content knowledge (Fulp, 2002). Both pre-service and practicing teachers reported low confidence in answering student science questions in three studies reported by Wenner (2001). Practicing teachers “desired an improvement in their own capabilities as teachers of science....[and] an improvement in their professional science knowledge” (Lewthwaite, 2005, p. 177) during a curriculum review project at a Canadian elementary school. Pre-service teachers in Turkey had low levels of science achievement and low confidence in teaching science in

a U.S.-modeled teacher education program that included several science content courses (Sarikaya, Cakiroglu and Tekkaya, 2005). In a study of pre-service elementary education students in England, Jarvis, McKeon and Taylor (2005) provided supplementary science instruction through small group activities. Small groups were formed and participated in science problem-solving activities that included considerable amounts of discussion rather than laboratory investigations. Students reported increased confidence in teaching science in post-session interviews. Akerson, Morrison and McDuffie (2006) found that pre-service teachers reverted to previous views of the nature of science in the months following a science methods course that targeted changing students' conceptions of the nature of science, suggesting that multiple exposures to foundational science courses are necessary before content is mastered.

The effect of science content courses at the general education level on science teaching efficacy was measured by Joseph (2003). In this study using the STEBI-B both elementary education majors and non-elementary education majors "were asked to consider themselves as an elementary teacher as they completed the [STEBI-B]" (Joseph, 2003, Instrumentation). The study included four populations of students: science majors who did not plan to teach, science majors who planned to teach elementary education, elementary education majors, and non-elementary, non-science majors who did not plan to teach. Both groups of science majors had a significantly higher Personal Science Teaching Efficacy (PTSE) than both groups of non-science majors. Elementary education majors (who only took general education science courses) did not have a significantly higher PSTSE than non-education non-science majors. She infers from this that "subject matter knowledge appears to be a factor in teacher efficacy and that confidence in

teaching ability is linked to knowledge of facts, skills and concepts in a subject matter” (Discussion, para.2).

Content mastery does not necessarily mean more college science courses for elementary education majors. Stevens and Wenner (1996), in a study of students in an elementary science teaching methods course found a significant correlation between science content knowledge and the number of high school science courses, but not college science courses. The authors suggest that “an increase in the number of college credit hours in science and mathematics content is less likely to effect necessary change than alteration of the methods and curriculum materials” (p. 2) in content courses.

It has become axiomatic that “teachers teach as they were taught.” If they are to teach science using inquiry and collaboration they must learn it the same way (NRC, 2000). Recent studies provide support for this contention. At an urban Midwest university, participation in an elementary program designed in accordance with the inquiry recommendations of the NRC produced significant positive correlation between attendance in inquiry-based science content courses and the ability to design inquiry-based lesson plans. Students in this program also scored significantly higher on a test of content knowledge than did students in traditional science courses (Luera, Moyer & Everett, 2005). At the University of Michigan, pre-service elementary education students in an inquiry-based series of science content courses showed greater gains in content knowledge and science teaching self-efficacy after two such courses than after none or only one (Luera & Otto, 2005). Interestingly in this study, three inquiry courses did not significantly increase science teaching self-efficacy over two courses, suggesting that optimal effects occurred with two inquiry courses. Inquiry-based biology courses in

Arizona produced teachers who provided more inquiry-based instruction, and whose students “demonstrated significantly higher achievement in terms of scientific reasoning, nature of science and biology concepts” (Adamson, et al., 2003, p. 939).

The benefits of improvements in content-based science courses for pre-service elementary teachers extend beyond graduation. In-service teachers report that they teach as they were taught, using active learning and inquiry pedagogy they experienced in their inquiry science content courses, in a small case-study of graduates from an elementary education program that used inquiry instruction for both content and methods courses (Lee & Krapfl, 2002).

#### *Pedagogical mastery and science teaching self-efficacy*

Much of the work on science teaching self-efficacy has been with pedagogical mastery, both in science methods courses and between education program levels. Tosun (2000), using a pre- and post-test design in a science methods course, found that prior science experience had no impact on the STEBI-B Personal Science Teaching Efficacy (PTSE) scale; however the science methods course improved PTSE significantly in students with both low and high levels of prior science experience. Jarrett (1999) found that a field-based inquiry science methods course increased both science interest and confidence in teaching science in a post-baccalaureate education certification program. Using a two-item Likert-style survey, initial science interest in this study was predicted by elementary and high school science experiences, while initial science teaching confidence was predicted by the number of college science courses. Sharmann and Hampton (1995) used the STEBI-B to measure science teaching self-efficacy in students enrolled in a cooperative hands-on science methods course. All cooperative groups,

whether heterogeneous, randomly formed, or self-selected, were found to have significantly increased PTSE after completion of the course when compared to pre-course results. However, it can be difficult to characterize interventions that occur in science methods courses as strictly pedagogical interventions, because most science methods courses incorporate science content as part of the instruction.

#### *Science teaching self-efficacy at the program level*

Enactive mastery experience exerts a powerful influence on science teaching self-efficacy, as Bandura (1997) asserts, yet content knowledge is critical as well, as Palmer (2006) suggests. Morrell and Carroll (2003) investigated segments of the elementary education program at a small private liberal arts university to determine which parts of the science-related program had the greatest effect on pre/post PSTE differentials. At this institution, elementary education students were required to take three general education science courses not specifically designed for education majors. These courses combined lecture and laboratory into a single course. In addition, elementary education students took a science teaching methods course and completed a science teaching field experience. Only the students with the lowest PSTE scores showed substantial gain after science content courses, while all students showed gains in PSTE scores after the science methods course. Student teachers did not show gains in PSTE scores; however, these were high on the pre-test. The authors conclude that the science methods course had the greatest impact on personal teaching efficacy, and that science content courses were effective at increasing teaching efficacy for only the lowest scoring group. The latter group is the one needing the greatest boost in efficacy, and the results indicate that science content courses can indeed serve to increase personal science-teaching efficacy.

Personal belief that one knows the content well enough to teach it, and actually having to teach it are two different issues. Cantrell, Young and Moore (2003) studied an elementary education program in which students were required to initially take three basic science content courses, along with a related one-hour education seminar course. This was followed by a six-hour methods course which included a three-week teaching practicum. The final tier of the program was a student teaching internship. The STEBI-B was administered at the end of each tier. At the initial level, males had overall higher PTSE scores than females, and students with more previous high school science courses had higher PTSE scores than those with fewer. Interestingly, participation in extracurricular science activities in high school had more impact on PTSE scores than the number of courses. Gender differences were not significant within the methods course group, however the number of previous high school science courses continued to produce significantly higher PTSE scores. At the student teacher level, none of the variables produced significant differences in PTSE. Comparing each tier, PTSE scores increased significantly after completion of the basic content course level and the methods course level; however, no significant difference appeared between the methods course and the student teaching level. This suggests that the experience of preparing a lesson and teaching it, as in a methods course, reinforces personal science teaching efficacy, as might be expected.

#### *Self-image and science teaching self-efficacy*

In Palmer's (2006) model effective teachers have high self-efficacy in science teaching due to content and pedagogical mastery and a positive image of self as a teacher of science. Vicarious experience contributes to self-image as a science teacher through

comparison with others (Ashton, Buhr & Crocker, 1984). The self-image as a science teacher is heavily influenced by mentoring and modeling during pre-service and early service experiences (Appleton & Kindt, 2002; Skamp & Mueller, 2001). Using video exemplars of good science teaching in a Hong Kong teacher education program, Wong, Yung, Cheng, Lam and Hodson (2006) found that these examples and the discussions that evolved from them helped prospective teachers to perceive themselves as teachers, and to begin the enculturation process of becoming teachers. Johnson, Kahle and Fargo (2006) used a classroom observation over a period of three years to determine that effective urban middle school science teachers impact student learning in positive ways, and that the impact is cumulative over time: the more effective science teaching a student experiences, the greater the achievement in both white and minority students.

Thus the cycle comes full circle. Positive attitudes and self-efficacy in science begin with active and cooperative learning, which are created in the classroom by effective science teachers. Effective science teachers themselves have high levels of science teaching self-efficacy due to positive self-images forged from effective role models; to content mastery gained through cooperative, active learning in science content and science methods courses; and to pedagogical mastery gained through both experience in cooperative and active learning, and through modeling by effective teachers in content and methods courses. Improving science teaching in elementary grades thus begins at the general education science content level by increasing science teaching self-efficacy in college students, and more specifically, elementary education majors.

## SCALE-UP

Self-efficacy is developed by mastery experience, vicarious experience, social comparison, and emotional state (Bandura, 1997), all of which can be influenced by the pedagogical and physical aspects of the learning environment (Moriarty, Douglas, Punch & Hattie, 1995). The SCALE-UP model incorporates both pedagogy and physical environment to enhance student learning.

### *What is SCALE-UP*

SCALE-UP (Student-Centered Activities for Large Enrollment Undergraduate Programs) is a studio-style model for large enrollment science classes that supports cooperative, inquiry-based learning. SCALE-UP was developed at North Carolina State University for inquiry learning in physics courses, and has been implemented in multiple science domains at 13 other institutions. The SCALE-UP model includes integration of lecture and laboratory in a single session, with carefully planned inquiry-based cooperative activities that engage student interest; classroom management techniques that reinforce cooperative learning; and use of technology to support cooperation and inquiry. Inquiry learning activities take place in a classroom that is specifically designed to maximize the benefits of small group cooperative and collaborative learning while housing large populations of students (Beichner & Saul, 2004; Beichner, Saul, Allain, Deardorff & Abbott, 2000).

### *Classroom design and student outcomes*

Research on classroom design and its affect on learning is recent and limited, and authors include psychologists, architects and educators. Early research in traditional classroom settings determined that proximity to the teacher produced definite behavioral



and academic effects. Stires (1980) found that college students who sat in the front had higher achievement levels, and that this was a function of the environment of the room/lecture hall and not the result of self-selection. Elementary grade students in the front of the room asked more questions (Moore & Glynn, 1984) and college students in the front rows were found to have higher levels of self-esteem (Hillmann & Brooks, 1991).

Classroom layout communicates the use of the space. “We go where the furniture tells us to go” according to Heyman (1978, p. 12). A 1996 Classroom Design Manual (Allen, et al.) recommended rows of desks with the instructor at the short end of a rectangular space for classes of 50-75, and lecture halls for classes of 75 or more. “Seminar” rooms accommodating students of 20 or less had more flexibility with rectangular or trapezoidal tables, but the teacher still had space in the front of the room. These arrangements placed the teacher squarely at the focus of information delivery and encouraged passive student participation.

In contrast to students in passive lecture mode, inquiry and cooperative learning places the responsibility for knowledge construction with the student. Classroom design features can enhance this learning and spaces where collaborative learning takes place need to communicate that message (Graetz & Goliber, 2002). Cornell (2002) reports that accounting students coming to a lecture hall began to settle in and prepare for listening, whereas students coming into rooms with desks set in small clusters began group conversations upon arrival. The features of cooperative spaces include: close visual contact between students; ease of visual contact with the teacher and instructional visuals; space between groups that provide some sense of spatial cohesion for the group; and ease

of access to learning materials (Johnson, Johnson & Holubec, 1994). For modern science classes in particular, ease of access to Internet and other electronic resources is critical (Graetz, 2006). In the SCALE-UP model at NCSU, nine students are seated around six-foot diameter tables, and work in teams of three, each team having a laptop computer. A teaching station in the middle of the room is connected to overhead projectors, which project onto two screens. The room contains multiple white boards that students use as public thinking spaces and SCALE-UP classrooms can hold 54 or 99 students (Beichner & Saul, 2004; Oliver-Hoyo & Beichner, 2004).

The design of learning spaces needs to proceed from learning principles and activities, not the other way around (Johnson & Lomas, 2005). “Pedagogy, the art and science of teaching, should be the driving force behind the design of any teaching facility. What is taught and how it is taught should determine the size, type, and configuration of educational space” (Stump & Swenson, 2005, p. 25). In a review of classroom environment studies, Woolner, Hall, Higgins, McCaughey and Wall (2007) found equivocal results for the effects of room arrangement on achievement. Some teachers continued to use new spaces in traditional ways, others modified existing spaces in order to implement different teaching strategies, and some used new spaces in new ways. As a result, some studies reported positive results for the effect of the room, while others reported no change.

Effectively designed learning space will not by itself enhance learning if the learning activities are not planned well (Horne, 1998). This is especially true when faculty desire to implement inquiry and cooperative/collaborative activities in large enrollment classes. In the SCALE-UP model class time is spent in collaborative work on

carefully planned inquiry-based hands-on activities as the learning environment shifts learning from a “teacher-centered classroom to a student-centered classroom” (Oliver-Hoyo & Beichner, 2004, p53).

#### *Student outcomes with SCALE-UP*

Higher academic achievement, better problem solving skills, and better understanding of physics concepts were reported for students in SCALE-UP sections than in traditional physics courses at NCSU (Beichner & Saul, 2004; Saul, Deardorff, Abbott, Allain & Beichner, 2000). Similar results were reported for chemistry students in SCALE-UP classes (Oliver-Hoyo, Allen, Hunt, Hutson & Pitts, 2004). Students in SCALE-UP classes did better in follow-up courses, whether traditional or SCALE-UP. Females did better in SCALE-UP classes than in traditional classes (Beichner and Saul 2004), an important result in light of research indicating low self-efficacy in science for this group (Osborne, et al., 2003; Pajares, 2002).

In a comparison of a traditional lecture/separate laboratory chemistry section with a SCALE-UP section of the same chemistry course, with the same instructor, Oliver-Hoyo and Allen (2005) found more positive changes in attitude toward learning science in the SCALE-UP section, but no significant overall difference in chemistry anxiety between sections. Qualitative responses in journals, interviews and focus groups indicate students in SCALE-UP feel the work is harder due to the need to be more prepared for class, but that they have a better understanding of the concepts than they would expect to have in a traditional course, and that they have a more positive attitude toward working in groups (Beichner, et al., 2000; Beichner & Saul, 2004; Oliver-Hoyo & Allen, 2005; Oliver-Hoyo & Allen, 2006; Oliver-Hoyo & Beichner, 2004; Saul, et al., 2000).

### *SCALE-UP in this study*

The SCALE-UP model was implemented at the host university as a means of accommodating large enrollments while honoring the cooperative and active learning principles of the university. Science teaching self-efficacy was measured in general education science students enrolled in courses utilizing the SCALE-UP model and was compared to the standard model in use at the university. Components of each model are described in Chapter 3, along with assessment instruments, and data collection and analysis methods.

## CHAPTER THREE: METHODS

This study investigated the effect of the SCALE-UP teaching model on science teaching self-efficacy of general education science students. The research design, data collection and data analysis are described in this chapter. The research design section includes a comparison of the two teaching models. A description of the population and sample selection process and a detailed description of the assessment instrument, including instrument validation, are included in the data collection section. Methods used for quantitative and qualitative analysis of the data are described in the final section.

### Research Design

This study took place at a small but rapidly growing public university in the southeast United States. The SCALE-UP teaching model was the treatment and was contrasted with the standard model of teaching (control) at the university. The study used a quasi-experimental nested 2x2 factorial design. Independent variables were gender and teaching model. Science teaching self-efficacy was the dependent variable. General education science courses and sections utilizing each model were selected to provide equivalent numbers of students in each sample. Multiple faculty and disciplines were included in each sample in order to elucidate the impact of the SCALE-UP model on the broad general education science student population. A frequently used and validated instrument for measuring science teaching self-efficacy, the STEBI-B (Enochs & Riggs, 1990; Bleicher, 2004) was selected and revalidated for use in this population. Open-ended questions related to student experience were included in the study to enrich the numerical findings.

### *Comparison of teaching models*

The standard model in use at the university and the SCALE-UP model have several important differences. General education science was taught in small studio-style rooms which combined lecture and laboratory in single sections. Standard model delivery encouraged active and cooperative learning, which faculty implemented according to individual syllabi. Lecture was commonly used, with added laboratory or group activities. “Group work” was a common thread throughout the science departments, and may or may not have been inquiry oriented. Group activities could include laboratory investigations, short in-class projects and long-term projects with end-of-project presentations. A common syllabus was used among faculty in some courses, while faculty in other courses developed individual syllabi.

In contrast, at NCSU the SCALE-UP model course activities were planned so that students encountered course content prior to class time, and class time was used for investigative, inquiry activities that utilized higher order thinking. Class time was spent on inquiry, with minimal lecture, and classroom management techniques such as random grading of group assignments were used to focus group learning (Oliver-Hoyo &Beichner, 2004). At the host university for the present study, faculty teaching general education science courses were given access to research material and attended seminars given by NCSU faculty on implementing the SCALE-UP model. Each faculty member utilizing a SCALE-UP room then developed activities and incorporated classroom management techniques for use in his/her course. The present study did not evaluate course syllabi for adherence to the SCALE-UP model, nor was classroom observation part of this research. Faculty involved in the study felt that such evaluations could be a

conflict of interest and/or could result in a judgment of teaching skill that could affect personal annual evaluations.

Standard model rooms at the host university contained desks or sectional tables for student seating and also high octagonal laboratory table spaces (Figure 2). Seating at the high tables was on tall, wheeled chairs. Traditional desks and short chairs at sectional tables were non-wheeled and less moveable. Electrical outlets and LAN connections were located on the laboratory tables. A multi-media electronic podium was located at the front of the room, with ceiling mounted projectors and a front projection screen. The electronic podium had a VCR, camera and PC computer with Internet and CD-ROM/DVD components. All visuals could be projected from the ceiling mounted projector. The podium was used extensively for teacher lectures (PowerPoint), videos, and Internet, and for student demonstrations and presentations. A whiteboard was mounted in the front of the room. Equipment storage and sinks were located around the sides of the room, along with an emergency shower and eyewash station. General education science course enrollment in these rooms was limited to 35 students by agreement between faculty and administration.



Figure 2: Example standard model room

SCALE-UP model courses at the host university were taught in rooms modified to accommodate 81 students. SCALE-UP-model rooms contained nine large round tables that seated nine students each (Figure 3). These tables were of normal (sitting) table height, compared to the higher (standing) tables in the standard model rooms. Wheeled chairs were used in SCALE-UP rooms to provide for added mobility. There was no separate seating other than at the immovable tables. Each table had electrical outlets and LAN connections. Each SCALE-UP room had an electronic podium with the same capabilities as the standard room podium, however in the SCALE-UP room there were two ceiling mounted projectors and projection screens in both the front and the back of the room to facilitate viewing from all positions at the tables without having to move chairs. Whiteboards lined the walls on three sides. Equipment storage and sinks were



located on one side of the room, along with an emergency shower and eyewash station. Wireless Internet access was available in both standard rooms and SCALE-UP rooms.



Figure 3: Example SCALE-UP model room

### *Variables*

This study evaluated the effect of four independent variables on four dependent variables. Independent variables in this study were the teaching models (SCALE-UP model vs. standard model), student major, student gender, and number of previous science courses. Dependent variables were student PTSE score on the modified Self-Efficacy Belief Instrument-B (STEBI-B; Bleicher, 2004), course enrollments, withdrawal rates, and pass/fail rates. Data for the latter were obtained from the host university enrollment and tracking system.

Extraneous or uncontrolled variables included course discipline (Human Systems, Marine Systems, and Environmental Biology); course syllabus, schedule and activities; course instructor; course time/day; and technology/room accommodation problems (e.g. temperature, internet accessibility, etc.)

### Data Collection

#### *Population and sample selection*

Students registered in daytime general-education science courses in the Fall 2006 and Spring 2007 semesters comprised the study population. These students either self-selected courses and sections based on schedule availability or were assigned to particular sections by advisors. Although the design was one of convenience sampling, the demographic distribution of students among sections was assumed to be equal due to the nature of section enrollments. Only daytime sections were used in the study to further control demographic variability.

All general education science courses in this study were designated “C” courses, in which laboratory and lecture were combined in a single section. Lecture-only general education science courses were not used in this study. Three general education science courses were selected for study: Human Systems, only taught in SCALE-UP rooms; Marine Systems, taught in both SCALE-UP and standard model rooms; and Environmental Biology, only taught in standard model rooms. All sections of the Human Systems course were taught by the same instructor in the SCALE-UP room and used the laboratory workbook designed originally for the standard model. The Marine Systems course used laboratory workbooks originally designed for the standard model in both the SCALE-UP room and standard model rooms. One instructor taught Marine Systems in

both room designs in different semesters, another instructor only taught Marine Systems course in the SCALE-UP room, and two other instructors only taught Marine Systems in the standard rooms. Environmental Biology instructors prepared their own syllabus and laboratory activities, and all were taught in standard model rooms. Seven of the eight Environmental Biology sections in this study were taught by the same instructor.

All sections of daytime general education science courses using the SCALE-UP model (Human Systems and Marine Systems) were selected for use in both semesters: three in the Fall 2006 semester, and three in Spring 2007. Multiple sections of daytime general education science courses using the standard model (Marine Systems and Environmental Biology) were available for selection. Sections taught by the author and a committee member were eliminated from the available pool. Of the remaining sections, five Fall semester sections and six Spring semester sections were selected to provide the greatest diversity of instructors and disciplines. Teaching model, semester, course, section enrollment and number of different instructors are listed in Table 1.

Table 1: Model and Section Enrollment by model, with number of sections and number of instructors

| Course                    | Model    | Sections<br>Fall/Spring | Instructors<br>Fall/Spring | Fall/Spring<br>Enrollment | Total<br>enrollment |
|---------------------------|----------|-------------------------|----------------------------|---------------------------|---------------------|
| Human Systems             | SCALE-UP | 2/2                     | 1/1                        | 156/150                   |                     |
| Marine Systems            | SCALE-UP | 1/1                     | 1/1                        | 75/76                     | 457                 |
| Environmental<br>Biology  | Standard | 4/4                     | 2/1                        | 139/126                   |                     |
| Marine Systems            | Standard | 1/2                     | 1/2                        | 34/64                     | 363                 |
| Total initial enrollment* |          |                         |                            |                           | 820                 |

\*See Table 3 for sample population

### *Assessment instrument*

The assessment instrument used in this study was the Science Teaching Efficacy Belief Instrument-Preservice (STEBI-B) for pre-service elementary teachers developed and validated by Enochs and Riggs (1990), and modified by Bleicher (2004). A copy of the instrument may be found in Appendix A. The STEBI-B was chosen because it addresses self-efficacy in teaching science of future elementary teachers, a critical population of general-education science students; it is not domain specific and therefore can be used across general education science courses regardless of content; it has been validated and widely used in studies of pre-service elementary education teachers; and it was used with non-science majors in at least one other study (Joseph, 2003).

The STEBI-B is a 23 item, 5-point Likert-scale survey that was initially validated by Enochs and Riggs (1990) and revalidated by Bleicher (2004), with minor word changes in two items. Bleicher's (2004) modified version was used. The STEBI-B has two factors, Personal Science Teaching Efficacy Belief (PSTE, 13 items: 2, 3, 5, 6, 8, 12, 17, 18, 19, 20, 21, 22, 23), which relates to personal confidence in science teaching ability, and Science Teaching Outcome Expectancy (STOE, 10 items), which relates to whether a pre-service teacher believes their teaching will have an effect on their students. Item responses range from *Strongly Agree* to *Strongly Disagree*.

The entire instrument was administered in this study, however only the results of the PSTE factor were used as a measure of personal efficacy. STOE, a measure of a teacher's ability to effect a change in student learning, was not a variable in this study. Because the STEBI-B instrument was validated using both sets of items, the entire instrument was included in the assessment. A PTSE score was generated for each

participant by summing the responses to the 13 PTSE items in the instrument, after recoding for reverse items.

Open-ended questions regarding the learning experience in each design were added to the instrument to enrich the numerical findings (Appendix A). Additionally, students were asked to identify their major, gender and total number of previous science courses (both high school and college.) The instrument was printed on a machine-readable form with adequate space to complete open-ended questions. The forms were serialized and no identifying information other than gender was requested.

#### *Instrument validation*

The STEBI-B instrument was developed and validated for use with pre-service elementary education majors by Enochs and Riggs (1990) and revalidated by Bleicher (2004) with slight modifications. The initial validation of the instrument produced Cronbach's alpha coefficients of .90 for PSTE, and .76 for STOE (Enochs & Riggs, 1990); revalidation by Bleicher (2004) with modification of two items, produced Cronbach's alpha coefficients of .87 and .72, respectively. However, the present study used this instrument in the general education science population, which is comprised of a variety of majors. Joseph (2003) used the STEBI-B in a similar population, but had not published the validation analysis (personal communication, January 16, 2007). Therefore validation of the instrument in this population was necessary.

The STEBI-B was administered in the Fall 2006 semester, as described below. Returned instruments were reviewed, also as described below. A total of 219 responses were used in the validation analysis using SPSS v.12. Items were reverse-coded as needed prior to analysis.

Using a non-rotated Principal Component Analysis, instrument items loaded on five components. All of the items for Personal Science Teaching Efficacy (PTSE) loaded on Factor 1 at .4 or higher, with the exception of Item 19, which loaded on Factor 1 (PTSE) as well as three other components, all below .4. This item reads “I wonder if I will have the necessary skills to teach science”. PSTE Items 5 and 12 both loaded on Factor 1 (PTSE) above .5 and also loaded on component 3 at -.5. Item 5 reads “I know the steps necessary to teach science concepts effectively,” and Item 12 reads “I understand science concepts well enough to be effective in teaching elementary science.” These items all mention science teaching skills, which may not be relevant for all of the majors in the sample, resulting in cross-loading of this item on multiple components in this population. Items relating to Science Teaching Outcome Efficacy (STOE) loaded on components 2 through 5 at .4 or above. STOE Item 9 loaded only on Factor 1 (PTSE) at .5. This item reads “The inadequacy of a student’s science background can be overcome by good teaching.”

This data set produced a Cronbach’s alpha of .87 for Factor 1 (PTSE); this is comparable to the alpha reported in both previous validation studies (Table 2). The second instrument factor, STOE, produced a Cronbach’s alpha of .62 in this study, which is lower than previous validation studies. This result is not unexpected, because STOE relates to teaching outcomes, a construct that was not relevant to most students in the sampled population.

Table 2: Reliability of the STEBI-B survey, previous and present studies

| Author                     | n   | Cronbach's alpha |      |
|----------------------------|-----|------------------|------|
|                            |     | PTSE             | STOE |
| Enoch & Riggs (1990)       | 212 | .90              | .76  |
| Bleicher (2004)            | 290 | .87              | .72  |
| This study, Fall 2006 data | 219 | .87              | .62  |

These results indicate the instrument is valid in the non-majors population for the PSTSE factor, and weakly valid for Enoch & Riggs' STOE factor. Although Cronbach's alpha is acceptable for measuring STOE in the present data, the fact that the items load on multiple components reduces the validity of the STOE score in this population.

#### *Administration of the instrument*

Internal Review Board (IRB) approval was obtained for the research from both the University of Central Florida and the host university (Appendix B). In addition, permission was obtained from each section instructor prior to administration of the instrument. In accordance with IRB directives, the survey was distributed to students and collected by the author at the beginning of the class, in the absence of the course instructor. Students were asked to consider themselves as elementary education teachers as they read and responded to the items in the survey.

Surveys were administered to one standard section in the 13<sup>th</sup> week of the Fall 2006 semester, and in the 15<sup>th</sup> week for the remaining standard and SCALE-UP sections. Spring 2007 administration took place in the 14<sup>th</sup> week for all but one standard section, which took place in the 15<sup>th</sup> week. One fall section of the standard model was surveyed

off-campus at a field trip location. The time frame in each semester was one to two weeks prior to exam week, and after the withdrawal date for each semester. The available enrollment in standard model courses at the time of survey administration was 355 students, and in the SCALE-UP model was 418 students, a total of 773 students (Table 3).

Table 3: Return rates for surveys in the sample population, between models

|  | Model    |          | Total |
|--|----------|----------|-------|
|  | SCALE-UP | Standard |       |
| Available population<br>(post withdrawal date) | 418      | 355      | 773   |
| Returned surveys                               | 262      | 271      | 533   |
| Discarded surveys                              | 42       | 43       | 85    |
| Useable surveys                                | 220      | 228      | 448   |
| Return rate*                                   | 53%      | 64%      | 58%   |

\*Return rate = useable surveys/available population

Returned surveys were reviewed for completeness, smudging, and other discrepancies prior to being machine scanned. Surveys with incomplete answers in any of the required data areas (age, gender, number of prior science courses, or survey items) were discarded from the sample pool. Surveys with smudged answers were transferred to a new sheet by the author. Surveys with single response or questionable response patterns, such as all “3”s or a consistent “Christmas-tree” pattern were discarded (n=85). Blank item responses on otherwise complete surveys were coded as “3” (undecided).

At the time of administration, multiple absences were noted in each section, resulting in a smaller potential sample pool. Of the surveys distributed, 533 were returned



completed, and 448 of these were found to be complete and useable. Using the post-withdrawal date enrollment in each section, rather than the actual attendance on the day of administration, an overall return rate of 58% was determined for useable surveys: 53% in SCALE-UP sections, and 64 % in standard sections (Table 3.)

Surveys were machine-scanned by the host university, and the data placed into an EXCEL spreadsheet, with serial number, gender and item response. Responses of *Strongly Agree* were coded as 5, *Agree* as 4, *Undecided* as 3, *Disagree* as 2, and *Strongly Disagree* as 1. In addition, the host university provided data on enrollment, withdrawal, and pass rates for each of the sections in question.

#### Data Analysis

Data from both semesters was combined prior to analysis. Reverse coding of items and dummy coding of variables (teaching model, gender, and major) was performed as needed. Individual majors as reported by students were combined into the following discipline groups: Visual and Performing Arts (art, theater and music), Health Science (athletic training and nursing), STEM (biology, environmental science, marine science, physics, veterinary medicine, statistics, and computers), Humanities (communication, English, history, philosophy, and law), Social and Behavioral Sciences (social work, sociology, psychology, political science), Criminal Justice (criminal justice and forensics), Business (accounting, business, marketing, and hospitality management), Education (all education, including elementary education), and Undeclared.

### *PTSE scores*

The value of items in the PSTE factor on the survey instrument (Items 2, 3, 5, 6, 8, 12, 17, 18, 19, 20, 21, 22, and 23) were summed to produce an overall PSTE score for each individual, ranging from 13 to 65. This score was used in the statistical analyses.

PSTE scores are ordinal in nature, therefore the Mann-Whitney  $U$  test for equivalence of medians was used to determine the significance of any difference in scores between students in SCALE-UP and standard model sections; between males and females within each model; between SCALE-UP and Standard model sections in Marine Biology; between SCALE-UP and standard model sections for the same instructor, and between SCALE-UP and Standard model sections for Education majors. Differences between males and females in SCALE-UP and standard models were evaluated using a two-way contingency table analysis ( $\chi^2$ ). The Kruskal-Wallis analysis of variance for ordinal data ( $\chi^2$ ) was used to evaluate differences in PTSE scores among discipline groups, among courses, and among instructors. Correlations between PTSE scores and number of previous science courses were determined using Kendall's tau-b. Kendall's tau-b is a rank-order test, and is the recommended test when there are multiple ties among ranks (Lomax, 2001). All statistical analyses were performed using SPSS v.12.

### *Open-ended questions*

Open-ended questions were appended to the STEBI-B survey in order to elicit student reactions to each teaching model. Questions were broad in nature so as to not lead students to a particular answer. The first question ("How does this room compare to other science rooms you have taken courses in?") was intended to draw student attention to the room itself and to provide a baseline for comparison with prior experiences. The second

and third questions (“What are the benefits of studying science in this room?” and “What are the drawbacks of studying science in this room?”) were intended to elicit student critique of the room structure and determine whether the SCALE-UP room design was perceived as conducive to cooperative learning compared to the standard room design. Question four (“How do the activities in this course compare to other science courses you have taken?”) was designed to provide feedback on the inquiry/active learning/cooperative learning experience of students in each model. Questions five (“What did you like about this course?”) and six (“How can this course be improved?”) are questions that have I have used frequently on end-of-semester evaluations. Question five provided affective information about student perceptions and emotional state, both of which are important to self-efficacy. Question six gave students an opportunity to provide constructive criticism, and the tenor of the suggestions provided insight to student affective state as well as what students consider positive or negative about a course. In this study, spontaneous responses to the last two questions that related to SCALE-UP parameters were particularly important because of the openness of the question.

Open-ended questions were individually reviewed and tabulated. Responses were grouped into common topics within SCALE-UP and standard model sections, and the rank and number of responses within each topic was compared between models. Overarching themes for each model were drawn from the topics and used to illuminate the quantitative findings.

Study methods described in this chapter included a validation of the instrument used as well as a description of the quantitative and qualitative analyses. Descriptions of the data as well as results of the quantitative analyses described herein are presented in

Chapter 4. Topics elicited from the open-ended questions are tabulated in Chapter 4, and discussed in Chapter 5. Chapter 5 discusses the results of the study, and provides conclusions and recommendations.

## CHAPTER FOUR: RESULTS

The Science Teaching Efficacy Belief Instrument (STEBI-B, Enochs & Riggs, 1990; Bleicher, 2000) was administered to non-science majors in general education science sections using either the SCALE-UP teaching model (Beichner, et al., 2000) or the standard teaching model in smaller studio-style rooms. Information on gender, number of previous science courses, and open ended questions regarding the learning experience were included in the assessment. Enrollment data were obtained from the university.

### Characteristics of the Population

#### *Gender and major distribution*

SCALE-UP model sections yielded 220 useable surveys, while standard sections returned 228 useable surveys. Females outnumbered males in both models (Table 4). Students listed a wide variety of majors, including a few science majors (psychology, environmental science, marine science, and biology) in each model. Specific majors were combined into discipline groups (Table 5). The most-listed discipline group was business, followed by humanities, education, and social and behavioral sciences.

Table 4: Distribution of genders between models

| Model    | Gender |        | Total |
|----------|--------|--------|-------|
|          | Male   | Female |       |
| SCALE-UP | 80     | 140    | 220   |
| Standard | 94     | 134    | 228   |
| Total    | 174    | 274    | 448   |

Table 5: Distribution of majors between models

| Discipline group                   | Model    |          | Total |
|------------------------------------|----------|----------|-------|
|                                    | SCALE-UP | Standard |       |
| Visual and performing arts         | 10       | 4        | 14    |
| Health science                     | 9        | 2        | 11    |
| Science, computers and mathematics | 9        | 12       | 21    |
| Humanities                         | 36       | 35       | 71    |
| Social and behavioral science      | 25       | 16       | 41    |
| Criminal justice                   | 20       | 16       | 36    |
| Business                           | 61       | 98       | 159   |
| Education                          | 28       | 36       | 64    |
| Undeclared                         | 22       | 9        | 31    |
| Total                              | 220      | 228      | 448   |

#### *Withdrawal and pass/fail rates*

Total enrollment, number of students withdrawn, and number of students receiving a grade of ‘F’ in each section were obtained from the university. The withdrawal rate and fail rate was calculated for each course type and model (Table 6; Figures 4 and 5). The overall withdrawal rate for the standard model was 2.2%, while the overall withdrawal rate for the SCALE-UP model was 8.8% (Figure 4). Fail rates in both models were similar: 7.6 % for the standard model, and 7.7% for SCALE-UP (Figure 5). Marine Systems sections exhibited higher withdrawal rates and fail rates than Human Systems sections in the SCALE-UP model, and lower rates than Environmental Biology in the standard model.

Table 6: Withdrawal and fail rates (n and %) by teaching model

| Model    | Course                | Initial enrollment | Number withdrawn/<br>withdrawal rate | Number fail/<br>Fail rate* |
|----------|-----------------------|--------------------|--------------------------------------|----------------------------|
| SCALE-UP | Human Systems         | 306                | 24/7.8%                              | 13/4.6%                    |
|          | Marine Systems        | 151                | 16/10.6%                             | 19/14.1%                   |
|          | Overall               | 457                | 40/8.8%                              | 32/7.7%                    |
| Standard | Environmental Biology | 265                | 7/2.6%                               | 23/8.9%                    |
|          | Marine Systems        | 98                 | 1/1.0%                               | 4/4.1%                     |
|          | Overall               | 363                | 8/2.2%                               | 27/7.6%                    |

\*Fail rate = Number of 'F' grades/enrollment after withdrawal date

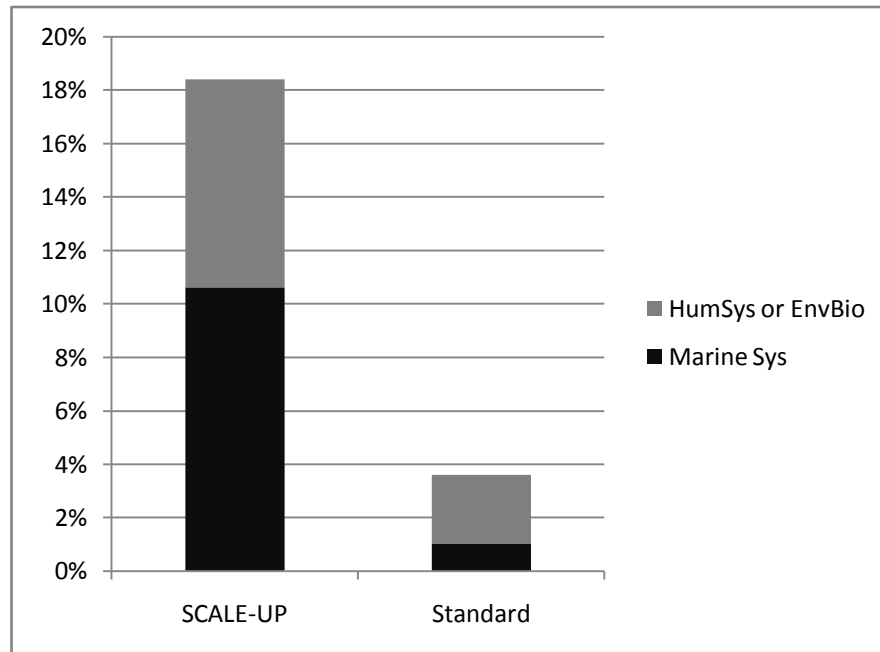


Figure 4: Withdrawal rates in each model, combined semesters

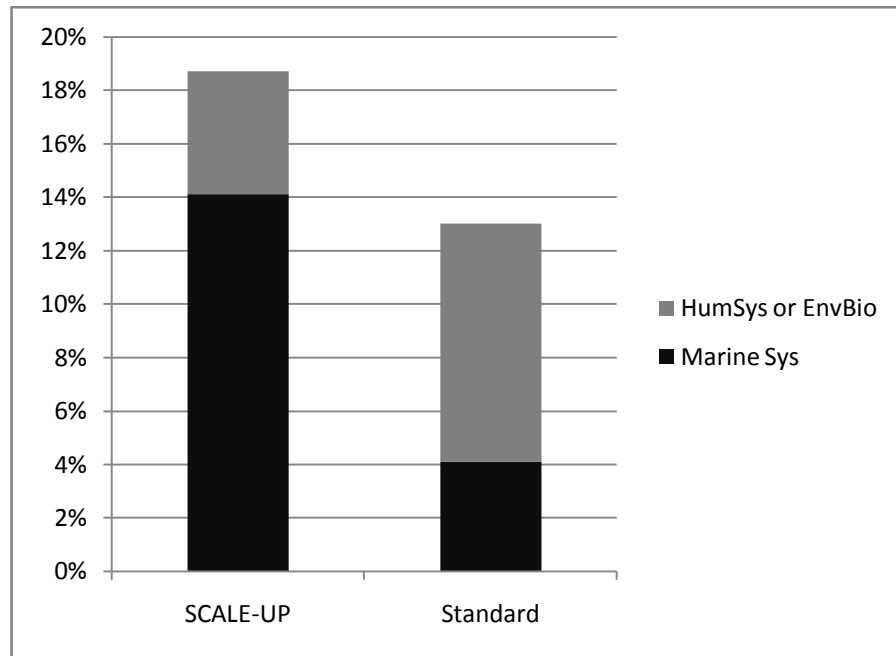


Figure 5: Fail rates in each model, combined semesters

#### *PTSE Scores*

PTSE scores for the SCALE-UP population ranged from 23 to 65, with a median score of 46. Scores for the standard population ranged from 26 to 64, with a median score of 46 (Figure 6).



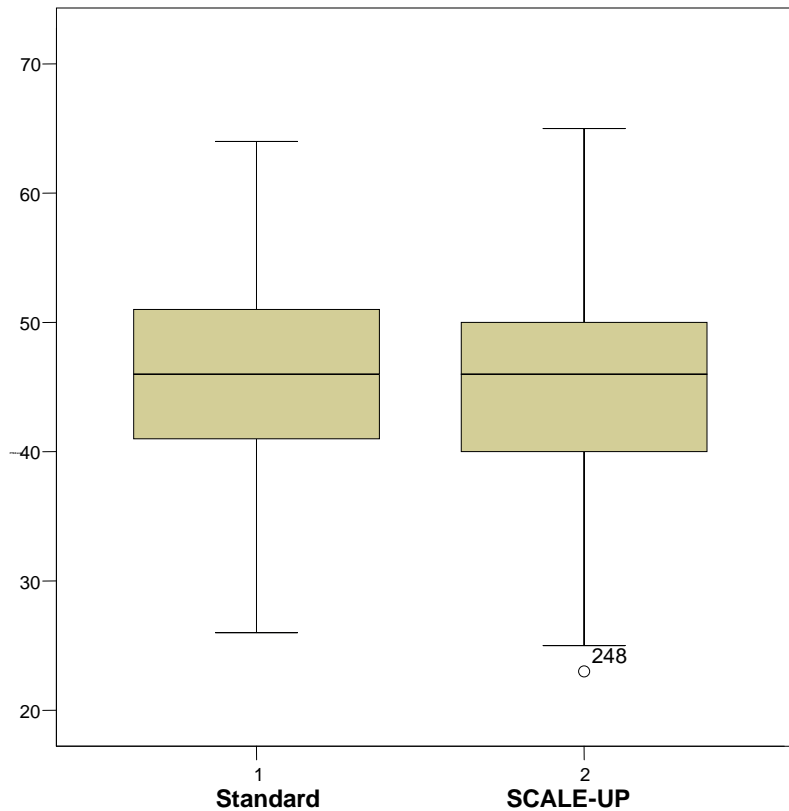


Figure 6: Boxplots of PTSE scores in each model

### Research Questions

Four research questions were formulated for this study, to evaluate the effects of the SCALE-UP model on Personal Science Teaching Efficacy of non-science majors. Each of the questions is enumerated below, along with results of the statistical analyses. Implications of these results are discussed in Chapter 5.

*Question 1: Is there a difference in the level of science teaching self-efficacy between students in the SCALE-UP courses and standard small enrollment courses?*

PTSE scores of students in the SCALE-UP model sample were compared to student scores in the standard model sample using a Mann-Whitney  $U$  comparison of medians test. No significant difference was found between median scores in these groups ( $z = -.923, p = .356$ ).

*Question 2: Is there a difference among majors in the level of science teaching self-efficacy overall and within each model (SCALE-UP vs. standard small sections)?*

The Kruskal-Wallis test for differences among medians ( $\chi^2$ ) was used to evaluate the effect of discipline group (major) on PTSE scores. No significant difference in PTSE scores was found among discipline groups in the overall population, [ $\chi^2 (8, N=448) = 9.33, p = .315$ ].

A significant difference was found among majors in the standard model sample, ( $\chi^2 (8, N=228) = 15.75, p = .046$ ); however, no significant difference was found in the SCALE-UP sample [ $\chi^2 (8, N=220) = 3.26, p = .917$ ].

*Question 3: Was there a difference between males and females in the level of science teaching self-efficacy overall and within each model?*

PTSE scores of males and females in the full population were compared using the Mann-Whitney  $U$  comparison of medians test. No significant difference was found between median scores in these groups ( $z = -1.170, p = .242$ ).

A two-way contingency table analysis was conducted to determine whether a PTSE score differential exists between males and females in SCALE-UP courses

compared to standard model courses. No significant relationship was found between gender and teaching model [Pearson  $\chi^2$  (1, n=448) = 1.115,  $p$  = .291].

PTSE scores of males and females within the SCALE-UP sample were compared using the Mann-Whitney  $U$  test. No significant difference was found between median scores in these groups ( $z$  = -1.606,  $p$  = .108).

PTSE scores of males and females within the standard model sample were compared using the Mann-Whitney  $U$  test. No significant difference was found between median scores in these groups ( $z$  = -.098,  $p$  = .922).

PTSE scores of males were compared between the SCALE-UP sample and the standard model sample, using the Mann-Whitney  $U$  test. No significant difference was found between median scores in these groups ( $z$  = -.295,  $p$  = .768).

PTSE scores of females were compared between the SCALE-UP sample and the standard model sample, using the Mann-Whitney  $U$  test. No significant difference was found between median scores in these groups ( $z$  = -1.426,  $p$  = .154).

*Question 4: Does the number of previous science classes affect the level of science teaching self-efficacy overall and within each design?*

The strength of correlation between number of previous science courses and PTSE scores was determined using Kendall's tau-b. The results are summarized in Table 7. In the total population, PTSE scores were found to be significantly correlated to the total number of previous science courses (tau-b = .148,  $p$  = .000); the number of previous high school science courses (tau-b = .124,  $p$  = .001); and the number of previous college science courses (tau-b = .088,  $p$  = .015).

Within the SCALE-UP sample, PTSE scores were found to be significantly correlated to the total number of previous science courses ( $\tau\text{-}b = .148, p = .003$ ); and the number of previous college science courses ( $\tau\text{-}b = .114, p = .028$ ); but not the number of previous high school science courses ( $\tau\text{-}b = .095, p = .072$ ).

Within the standard sample, PTSE scores were found to be significantly correlated to the total number of previous science courses ( $\tau\text{-}b = .147, p = .003$ ); and to the number of previous high school courses ( $\tau\text{-}b = .157, p = .002$ ); but not the number of previous college science courses ( $\tau\text{-}b = .054, p = .290$ ).

Table 7: Correlation coefficients: PTSE with previous science courses in each model

| Model    | N   | Total previous science | Previous high school science | Previous college science |
|----------|-----|------------------------|------------------------------|--------------------------|
| SCALE-UP | 220 | .148**                 | .095                         | .114*                    |
| Standard | 228 | .147**                 | .157**                       | .054                     |
| Overall  | 448 | .148**                 | .124**                       | .088*                    |

\*  $p < .05$

\*\*  $p < .01$

### Ancillary Analyses

Each of the two teaching models in this study, SCALE-UP and the standard model, included several courses and instructors. Additional analyses were performed to determine if PTSE scores differed among courses and instructors, regardless of teaching model.

### *Differences among courses*

Three different courses were taught in this study: Marine Systems, Environmental Biology, and Human Systems. The Kruskal-Wallis test for differences among medians ( $\chi^2$ ) was used to evaluate the effect of the course on PTSE scores. No significant difference in median PTSE score was found among courses [ $\chi^2$  (2, N=448) = 2.54,  $p$  = .280].

### *Differences among instructors*

Seven different instructors participated in this study. Differences in PTSE score among instructors were evaluated using the Kruskal-Wallis analysis of difference among medians ( $\chi^2$ ). No significant difference was found among instructors [ $\chi^2$  (7, N=448) = 9.69,  $p$  = .138].

### *Differences between teaching models within a single course*

The Marine Systems course was the only course taught using both of the models, SCALE-UP and standard. Using the Mann-Whitney  $U$  test for comparison of medians, no significant difference in PTSE scores was found between teaching models ( $z$  = -.061,  $p$  = .952).

One instructor taught Marine Systems using both models, in different semesters. Using the Mann-Whitney  $U$  test, PTSE scores were found to be significantly different between models for this instructor ( $z$  = -2.343,  $p$  = .019). Median PTSE score for the SCALE-UP model was 47 (n=27), while the median PTSE score for the standard model was 41.5 (n=24; Figure 7). Final enrollment in the SCALE-UP section was 66, however only 27 students completed surveys for a return rate of 41%. A return rate of 71% (24/34) occurred in the standard section for this instructor. Eighteen percent of students in

the SCALE-UP section failed the course, while six percent of students in the standard section received a grade of “F”. No differentiation was made between students who earned the grade of “F” and those who received a grade of “F” because they had not formally withdrawn from the course, but had stopped coming to class.

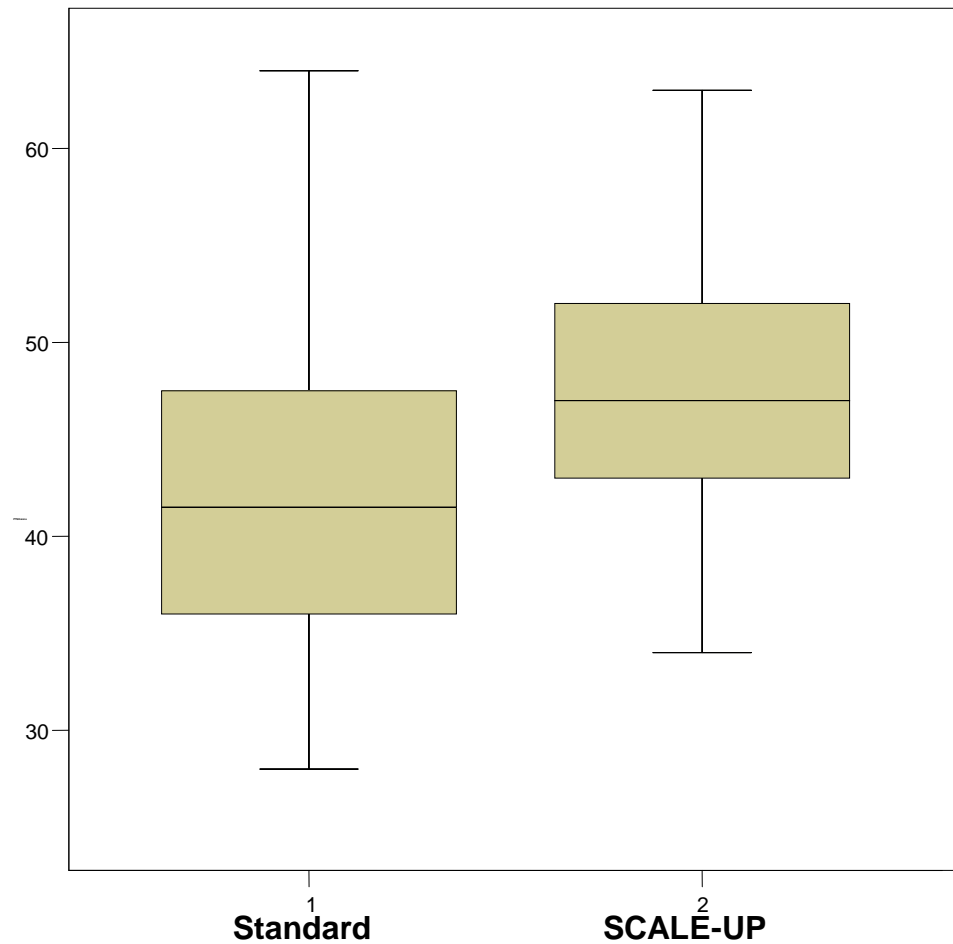


Figure 7: Boxplots of PTSE scores in each model, same course  
with the same instructor

### *Education majors*

Sixty-four education majors participated in this study; 28 in the SCALE-UP model, and 36 in the Standard model. These students were distributed among the courses and instructors. In the SCALE-UP sample, 20 students specified Elementary Education as their major, and 26 students in the standard section specified Elementary Education. All education majors were grouped together for this analysis. Education majors in the SCALE-UP model had a median score of 45 (range 25-59), while the median score in the standard model was 46.5 (range 37-54).

The Mann-Whitney *U* test was used to compare PTSE scores of education majors between teaching models. No significant difference was found between median scores in education majors ( $z = -1.255$ ,  $p = .210$ ).

Qualitative findings from the open-ended questions are summarized in the next section.

### Qualitative Findings

Six open-ended questions were asked on the survey instrument, and are enumerated below. These questions were designed to elicit responses from students that could illuminate the subjective experience of taking science courses in each model. The rationale for each question is discussed in Chapter 3. Findings are tabulated herein and discussed in Chapter 5.

The number of responses to the open-ended questions do not match the number of survey instruments because some students answered none of the open-ended questions, and some left a few of the questions blank (Table 8). Some students provided more than one answer for a question. Similar responses were grouped into topics, and dissimilar responses were not included in the tabulations.

Table 8: Response counts for open-ended questions in each model

| Question<br>Number | Model    |          |
|--------------------|----------|----------|
|                    | SCALE-UP | Standard |
| 1                  | 298      | 244      |
| 2                  | 265      | 238      |
| 3                  | 178      | 209      |
| 4                  | 216      | 232      |
| 5                  | 227      | 231      |
| 6                  | 186      | 175      |



*Open-ended Question 1:*

*“How does this room compare to other science rooms you have taken courses in?”*

Student responses to this question were tabulated and grouped into topics.

Different topics emerged for each of the models (Table 9). The highest response topic was “larger room” in the SCALE-UP model, while the highest for the standard model was “same or similar.” In order of response rate, SCALE-UP topics were “larger room,” “round tables,” “larger class size,” “same or similar,” and “allows for student interaction.” Standard model topics, in order of response rate, included “same or similar,” “larger room,” “smaller room,” “better equipped,” “different arrangement,” and “lab tables.”

Table 9: Topics for *Open-ended Question 1* in each model

| Topic                          | Model          |      |                |      |
|--------------------------------|----------------|------|----------------|------|
|                                | SCALE-UP       |      | Standard       |      |
|                                | Response count | Rank | Response count | Rank |
| Larger room                    | 69             | 1    | 20             | 2    |
| Round tables                   | 27             | 2    | 8 (“tables”)   | 7    |
| Larger class size              | 23             | 3    | (0)*           | -    |
| Same or similar                | 22             | 4    | 88             | 1    |
| Allows for student interaction | 17             | 5    | (5)            | -    |
| More open                      | 14             | 6    | (4)            | -    |
| No lab benches                 | 14             | 6    | (0)            | -    |
| Group tables                   | 13             | 7    | (3)            | -    |
| Better science design          | 10             | 8    | (5)            | -    |
| Different arrangement          | 10             | 8    | 10             | 5    |
| Smaller                        | (2)            | -    | 16             | 3    |
| Better equipped                | (8)            | -    | 16             | 4    |
| Lab tables                     | (0)            | -    | 9              | 6    |
| Less equipment                 | (5)            | -    | 8              | 8    |

\*(n) included for comparison purposes: not a topic for this model

*Open-ended Question 2:*

*“What are the benefits of studying science in this room?”*

Similar topics emerged for both model in response to this question (Table 10).

The highest number of responses in the SCALE-UP model was overwhelmingly “group work is easier,” followed by “projector/electronic podium,” and “space to work.”

Standard model responses, in order, were “lab space in the room,” “access to equipment,” and “more professor attention.”

Table 10: Topics for *Open-ended Question 2* in each model

| Topic                       | Model          |      |                |      |
|-----------------------------|----------------|------|----------------|------|
|                             | SCALE-UP       |      | Standard       |      |
|                             | Response Count | Rank | Response count | Rank |
| Group work is easier        | 111            | 1    | 40             | 2    |
| Projector/electronic podium | 38             | 2    | 15             | 5    |
| Space to work               | 30             | 3    | 18             | 4    |
| More professor attention    | 9              | 4    | 23             | 3    |
| Access to equipment         | 8              | 5    | 40             | 2    |
| Lab space in the room       | (0)*           | -    | 41             | 1    |
| Feels like a science room   | (4)            | -    | 13             | 6    |
| Hands-on                    | (6)            | -    | 10             | 7    |

\*(n) included for comparison purposes: not a topic for this model

*Open-ended Question 3:*

*“What are the drawbacks of studying science in this room?”*

Similar topics emerged for both models in answer to this question. Both models had high responses of “none/no drawbacks” (Table 11). This topic was treated as a separate response from blank answers. SCALE-UP students indicated “crowded” as the

biggest drawback, followed by “distracting/noisy” and “lack of professor attention”. Standard model students indicated “too cold” as the biggest drawback, followed by “distracting,” “crowded,” and “can’t see/can’t move chairs.” Numbers in parentheses are included for comparison purposes; those were not major topics for that model.

Table 11: Topics for *Open-ended Question 3* in each model

| Topic                               | Model          |      |                |      |
|-------------------------------------|----------------|------|----------------|------|
|                                     | SCALE-UP       |      | Standard       |      |
|                                     | Response Count | Rank | Response Count | Rank |
| Crowded                             | 46             | 1    | 23             | 4    |
| No drawbacks                        | 40             | 2    | 59             | 1    |
| Distracting/noisy                   | 40             | 2    | 24             | 3    |
| Lack of professor attention         | 36             | 3    | (1)*           | -    |
| Can’t see/can’t move chairs         | 21             | 4    | 18             | 5    |
| Too cold                            | (2)            | -    | 28             | 2    |
| Didn’t like syllabus/tests/lectures | (4)            | -    | 10             | 6    |

\*(n) included for comparison purposes: not a topic for this model

#### *Open-ended Question 4:*

*“How do the activities in this course compare to other science courses you have taken?”*

Similar topics between models again emerged in response to this question (Table 11). SCALE-UP students responded with “more hands-on,” “same/similar,” “more labs,” and a tie between “broader/easier” and “more in-depth/harder.” Standard model students responded with “more field trips,” “more hands-on,” “same/similar,” and “more interesting.” Response rates and ranks are listed in Table 12.

Table 12: Topics for *Open-ended Question 4* in each model

| Topic                 | Model          |      |                |      |
|-----------------------|----------------|------|----------------|------|
|                       | SCALE-UP       |      | Standard       |      |
|                       | Response Count | Rank | Response Count | Rank |
| More hands-on         | 36             | 1    | 41             | 2    |
| Same/similar          | 32             | 2    | 28             | 3    |
| More labs             | 19             | 3    | 11             | 5    |
| Broader/easier        | 18             | 4    | 9              | 6    |
| More in-depth/ harder | 18             | 4    | (2)*           | -    |
| More interesting      | 15             | 5    | 24             | 4    |
| Less hands-on         | 13             | 6    | (8)            | -    |
| More field trips      | (0)            | -    | 57             | 1    |
| Less labs             | (4)            | -    | 9              | 6    |

\*(n) included for comparison purposes: not a topic for this model

*Open-ended Question 5:*

*“What did you like best about this course?”*

Not surprisingly, fewer common topics emerged between models in response to this question (Table 13). SCALE-UP students reported liking the following, in order: “labs/activities,” “teacher,” “group work,” “ease/comfort level,” and “nothing.” Standard model students reported liking: “field trips,” “teacher,” “labs/activities,” and “hands-on.”

Table 13: Topics for *Open-ended Question 5* in each model

| Topic                | Model          |      |                |      |
|----------------------|----------------|------|----------------|------|
|                      | SCALE-UP Model |      | Standard Model |      |
|                      | Response Count | Rank | Response Count | Rank |
| Labs/activities      | 55             | 1    | 23             | 3    |
| Teacher              | 26             | 2    | 39             | 2    |
| Group work           | 18             | 3    | (6)*           | -    |
| Ease/rigor level     | 16             | 4    | (1)            | -    |
| Nothing              | 15             | 5    | (2)            | -    |
| On-line              |                |      |                |      |
| quiz/syllabus        | 12             | 6    | (2)            | -    |
| Course-specific      |                |      |                |      |
| items (e.g. journal) | 11             | 7    | 15             | 5    |
| Hands-on/active      | 9              | 8    | 16             | 4    |
| Field trips          | (7)            | -    | 83             | 1    |

\*(n) included for comparison purposes: not a topic for this model

*Open-ended Question 6:*

*How can this course be improved?*

Fewer common topics also were apparent in response to this question (Table 14).

SCALE-UP students would improve the course with “less lecture/more lab,” “less rigor/teach at non-science major level,” “smaller class size,” and “better teacher.”

Standard model students would improve the course with “less lecture/more labs,”

“shorter class period,” “no changes,” and “more field trips.” Numbers in parentheses are included for comparison purposes; those were not major topics for that model.

Table 14: Topics for *Open-ended Question 6* in each model

| Topic                               | Model          |      |                |      |
|-------------------------------------|----------------|------|----------------|------|
|                                     | SCALE-UP       |      | Standard       |      |
|                                     | Response Count | Rank | Response Count | Rank |
| Less lecture/more labs              | 42             | 1    | 36             | 1    |
| Less rigor/teach at n-s major level | 25             | 2    | 10             | -    |
| Smaller class size                  | 13             | 3    | (0)*           | -    |
| Better teacher                      | 11             | 4    | (5)            | -    |
| No changes                          | 10             | 5    | 23             | 3    |
| More student participation          | 8              | 6    | (6)            | -    |
| Shorter class period                | 8              | 6    | 32             | 2    |
| More field trips                    | (0)            | -    | 12             | 4    |

\*(n) included for comparison purposes: not a topic for this model

The ranked responses to each of the open-ended questions were merged into four broad themes: physical aspects (includes size, space/crowded, temperature, tables, electronic equipment, laboratory equipment/supplies, etc), teacher attention, student group interaction, and course activities. These themes are discussed further in Chapter 5.

Quantitative and qualitative results from this study have been tabulated in this chapter. Chapter 5 discusses the results, implications for the SCALE-UP teaching model as used in the university, and recommendations for future research.

## CHAPTER FIVE: DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

Science teaching self-efficacy was measured in non-science majors taking general education science courses at a small public university in the southeast United States. These courses employed one of two teaching models: the Student Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP, Beichner & Saul, 2004), or the standard model in use at the institution. The SCALE-UP model incorporated inquiry-guided learning in collaborative groups, in a classroom arrangement of round group tables which housed 81 students. The standard model incorporated lecture and cooperative group activities in a studio-style classroom arrangement with both desks/small tables and separate laboratory benches. The standard model housed 35 students per section. Science teaching self-efficacy was measured using the Science Teaching Belief Instrument-B, (Enochs and Riggs, 1990; Bleicher, 2004) for use with elementary education majors. Item response values for the Personal Science Teaching Efficacy (PTSE) factor were summed to produce a PTSE score for each individual.

The results for the four research questions are discussed first, followed by a discussion of the six open-ended questions included as part of the assessment. The final section of this chapter presents conclusions and recommendations for future research.

### Research Questions

*Question 1: Was there a difference in the level of science teaching self-efficacy between students in the SCALE-UP courses and standard small enrollment courses?*

*Hypothesis 1: The SCALE-UP model would have a positive effect on science teaching*

*self-efficacy of non-science majors, compared to the standard model.*

No statistical difference in PTSE score was found between students enrolled in SCALE-UP and standard model courses. The hypothesis was not supported. Both samples had a median PTSE score of 46, with a range of 23 to 65 in the SCALE-UP sample, and a range of 26 to 64 in the standard model. The score range of the instrument is 13 to 65, with a median of 39. Both samples exhibited ranges and medians higher than the instrument median (46 compared to 39). The higher median in the population is probably not reflective of any influence of either course model. In Morrell and Carroll's (2003) study of elementary education majors, the mean PTSE score was 47.80 following general education content courses (n=46). Although mean scores were not used for statistical analysis in this study, mean scores in the study samples were 44.95 in the SCALE-UP sample, and 45.83 in the standard sample, similar to Morrell and Carroll's.

The lack of a significant difference in median PTSE scores between models may be due to the influence of several of the uncontrolled variables, alone or in combinations. Course content differed between models, course instructors differed between models, and course syllabi/activities differed between models.

The standard teaching model at this school included what is usually referred to as "group activities." These activities varied between courses and instructors. After the data were collected for this study, a workshop on implementation of SCALE-UP was held at the institution. Instructors using the SCALE-UP teaching model reported using the same or similar syllabi and activities as had been used previously in the standard size rooms. Follow-up emails with SCALE-UP instructors determined that, while a common syllabus was in place for both Human Systems and Marine Systems, limited changes were made



when the course was taught in SCALE-UP mode, compared to standard mode. In this scenario, the lack of increase in median PTSE score in the SCALE-UP model is not surprising.

Conversely, no decrease was seen in median PTSE score in the larger SCALE-UP room, as might be expected from more than doubling the course enrollment. This suggests that while larger class sizes may be perceived as negative, the impact of class size on science teaching self-efficacy is more a product of pedagogy than of class size. Ebert-May, et al. (1997) found positive results for inquiry and cooperative learning in large enrollment lecture classes, compared to traditional large lecture.

Given the diversity of course content and instructor variety, additional analyses were conducted to determine whether PTSE scores varied with content or instructor. No significant difference in median PTSE score was related to either content or instructor. This suggests that either a uniform distribution of science teaching self-efficacy was present in the population unaffected by content, instructor or teaching model, or that the diversity in content and instructor was so great that PTSE differentials for teaching models could not be determined.

One contrast did result in a significant difference, however. In one instance, the same instructor taught the same course under both teaching models. For this instructor, median PTSE score was significantly different between the SCALE-UP model and the standard model, with the SCALE-UP sample having a larger median score than the standard sample. The instructor indicated that the common syllabus was used, but that an effort was made to include more group/team activities that were inquiry-oriented in the SCALE-UP section (Anonymous, personal communication, February 16, 2008).

While this modification may have contributed to the larger median PTSE score, alternative explanations are possible. Thirteen percent of students withdrew from the SCALE-UP course prior to administering the survey and only 41% of the remaining students completed the survey (n=27). This compares to zero withdrawal from the standard course and 71% of the students completing the survey (n=24). The students completing the survey in the SCALE-UP course were thus likely to be the remaining, better performing students. The significant difference in median PTSE score between models for this instructor is therefore suspect due to possible sampling bias.

*Question 2: Was there a difference among majors in the level of science teaching self-efficacy overall and within each model (SCALE-UP vs. standard small sections)?*

*Hypothesis 2a: There would be a difference among majors in science teaching self-efficacy overall.*

*Hypothesis 2b: The SCALE-UP model would reduce the relative difference in science teaching self-efficacy among majors in comparison to the standard small enrollment model.*

No significant difference in median PTSE score was found among major discipline groups in the overall population. Hypothesis 2a was not supported. Within each model, no significant difference was found among major disciplines in the SCALE-UP model; however median PTSE scores were significantly different among discipline groups in the standard model [ $\chi^2$  (8, N=228) = 15.75,  $p$  = .046]. While hypothesis 2b was supported, the absence of significance differences in the overall population renders interpretation of this significance problematic. It is possible that the SCALE-UP model

did reduce an effect due to discipline. Alternatively, the unequal distribution of discipline groups between samples was the root source of the significant differential in PTSE scores in the standard sample (for example, the SCALE-UP model had 4.5 times as many health science majors as the standard model). The implication of the findings has limited use in determining the value of the SCALE-UP model.

An additional analysis of PTSE scores was performed in the subsample of education majors. Although the median score for education majors in the SCALE-UP sample was 45, and in the standard sample the median score was 46.5, no significant difference was found between teaching models in this subsample. This result suggests that education majors at the general education level have no better and no worse levels of science teaching self-efficacy than other general education science students, and that the use of the SCALE-UP model in large enrollment sections did not decrease science teaching self-efficacy in this group.

*Question 3: Was there a difference between males and females in the level of science teaching self-efficacy overall and within each model?*

*Hypothesis 3a: Males would exhibit higher levels of science teaching self-efficacy than females overall.*

*Hypothesis 3b: The SCALE-UP model would reduce the relative difference in science teaching self-efficacy between females and males in comparison to the standard small enrollment model.*

No significant difference in median PTSE scores was found between males and females in the overall population, within the SCALE-UP model, or within the standard

model. Further, no significant difference was found in male median PTSE scores between the SCALE-UP model and the standard model; the same held true for female median PTSE scores. Neither hypothesis was supported. This result supports that of Joseph (2003), who found no significant difference between male and female mean PTSE scores in non-science majors.

Conversely, a discrepancy between male and female science teaching self-efficacy was found by Cantrell, et al. (2003) in elementary education majors. In their study, males ( $n=28$ ) reported mean PTSE scores of 51.14, while females ( $n=126$ ) reported mean PTSE scores of 48.12 after taking nine hours of general education science concurrent with three one-hour introductory science methods seminars. The difference in mean PTSE scores between males and females was significant for their population at  $p=.016$ . The authors suggested that the difference may be related to the higher number of previous science courses and the number of previous extracurricular science experiences reported in their male population.

In the present study, no significant difference was found between genders, yet the number of previous science courses is significantly correlated with median PTSE scores (see below). This result suggests that the cooperative learning practiced in the teaching models at this institution may reduce the gender gap in science teaching self-efficacy through peer interaction. Vicarious learning and verbal persuasion are important elements of cooperative learning that can enhance self-efficacy (Bandura, 1997.) An alternative explanation is that no gender gap existed between males and females in this population prior to the beginning of this study. It is not possible to distinguish between these two alternatives with the data available.

*Question 4: Did the number of previous science classes affect the level of science teaching self-efficacy overall and within each design?*

*Hypothesis 4a: Overall, students with more previous science classes would have higher science teaching self-efficacy than students with fewer previous science classes.*

*Hypothesis 4b: The SCALE-UP model would reduce the relative difference in science teaching self-efficacy among students with more and fewer previous science classes in comparison to the standard small enrollment model.*

Small but significant correlations were found between the total number of previous science courses and median PTSE score in the overall population; between the number of previous high school science courses, and median PTSE score; and between the number of previous college science courses and median PTSE score (Table 7.)

Hypothesis 4a was supported. This result parallels results found in other studies limited to elementary education majors (Cantrell, et al., 2003; Jarrett, 1999; Kumar & Morris, 2005).

Using the STEBI-B, Cantrell, et al. (2003) found that the number of high school science courses was significantly correlated with PTSE scores in both male and female preservice elementary education majors when measured after science content courses, but before methods courses. They suggest that higher levels of PTSE in males relative to females was due to higher numbers of high school science courses taken by males in their sample, and to higher levels of extracurricular science experienced by males.

Jarrett (1999), found that the number of previous college science courses predicted “confidence in science teaching” in a Master’s-level program for elementary teachers, while Kumar and Morris (2005) found that college chemistry and physics

courses contributed more towards “attitudes toward science” in preservice elementary teachers than did high school chemistry and physics.

In this study, median PTSE score in each sample (SCALE-UP and standard) was also evaluated in relation to the total number of previous science courses, and the number of previous high school and college courses separately (Table 7.) In both samples, the total number of previous science courses had a small but significant correlation to PTSE score. However, only high school science courses was significantly correlated with PTSE scores in the standard model, whereas only previous college science courses was significantly correlated with PTSE scores in the SCALE-UP model.

The small size of the correlations and the mixed results between models provides limited useful information in determining the impact of the SCALE-UP model on science teaching self-efficacy. As with the findings for Question 2 the results may be more attributable to the distribution of the number of previous science course in each model, than to the impact of the model on PTSE.

### Qualitative Findings

Student retention rates and pass/fail rates can be indicators of course success. While students may withdraw for many reasons, a high withdrawal rate can provide a non-specific indication of problems. The overall withdrawal rate for SCALE-UP courses was four times higher than for courses in the standard model, with a higher percentage in the Marine Systems course than in the Human Systems course (Table 6.) Fail rates in both models were similar (7.7% and 7.6%), however, the fail rate in the SCALE-UP version of the Marine Systems course was three times higher than both the Human Systems (SCALE-UP) course, and the Marine Systems standard model. While it is

tempting to use these results to suggest a benefit for the standard model, it would be inappropriate to do so in light of the diversity of disciplines, syllabi, and instructors in the study. This finding supports the suggestion that the diversity in this study may be one reason for the lack differentiation in median PTSE scores between the two models.

In addition to the assessment items on the STEBI-B instrument, students were asked to respond to six open-ended questions on the survey:

1. How does this room compare to other science rooms you have taken courses in?
2. What are the benefits of studying science in this room?
3. What are the drawbacks of studying science in this room?
4. How do the activities in this course compare to other science courses you have taken?
5. What did you like best about this course?
6. How can this course be improved?

Because these questions were broad and open-ended, responses were quite varied. As a result, the number of responses in each ranked topic was relatively low. Narrower questions and/or limits on the response categories may have produced higher numbers in each topic, but the full range of possible responses would not be available. This lends greater credence to the topics which did emerge.

Across all six questions, four broad themes were evident in the SCALE-UP model: the physical arrangement/conditions in the room, teacher attention, student group interaction, and course activities.

### *Physical aspects*

As may be expected, students noticed the size of the room, the round tables and lack of laboratory bench space in the SCALE-UP rooms; similarly, a different room arrangement (tables and benches in the same room) was noticeable in the standard room. Interestingly, seventeen students specifically said the SCALE-UP room arrangement allows for student interaction. Electronic equipment, including the multimedia projector was considered a benefit in both rooms. Both rooms were considered crowded and distracting, moreso in the SCALE-UP room than in the standard room. Students reported not being able to see or move chairs in both rooms. The arrangement of round tables with screens at both ends of the room was a specific design component of SCALE-UP at NCSU to foster cooperative work and still enable students to see projected material (Oliver-Hoyo & Beichner, 2004). Eighteen students in the standard model and 21 students in the SCALE-UP model reported the lack of visibility as a drawback.

Large numbers of students working together in a single room can be noisy. In addition, round tables that foster group interaction may also lead to off-topic conversations during times of instruction or lecture. Distractions such as these were reported in both models but more frequently in the larger SCALE-UP room. These problems are inherent in classroom management rather than the teaching model, but are magnified in large enrollment sections. Strategies to reduce distracting behavior, and perhaps some acoustic modifications would benefit learning in both rooms.

### *Teacher attention*

Teacher attention was an important component of student experience in both models. “More professor attention” ranked third in student responses as a benefit of the



room in the standard model, while “lack of professor attention” ranked third as a drawback of the room in the SCALE-UP model. Several of the SCALE-UP sections had one or more teacher assistants to help with student questions, yet students still reported a lack of attention as a drawback. This is a function of the enrollment in the course, which is supported by the room size. SCALE-UP rooms hold more than double the number of students than standard rooms (81 in SCALE-UP and 35 in standard rooms).

In addition, the use of group activities may reduce individual teacher attention. Students unaccustomed to cooperative learning may feel abandoned by the instructor required to learn cooperatively. Also, when the group is larger (nine in the SCALE-UP model compared to three-to-five in the standard model) or when there are more groups (for example, when the nine students at a table are divided into three groups), the amount of time needed to attend to group questions may be greater. This reduces the amount of time available for the individual attention that may be needed for discussion of grades or other individual matters.

#### *Student group interaction*

Group interaction was considered separately from activities that may involve group cooperation. While these constructs may overlap, student responses seemed to differentiate them. Many more students in the SCALE-UP rooms than in the standard room reported that ease of group work was a benefit of the room (111:40). SCALE-UP students also indicated that the room arrangement benefits group work and that what they liked best about their science course was the group work (18 compared to six in the standard room).

While median PTSE scores did not differ between the models, students apparently did relate to the cooperative focus of the SCALE-UP model. This may be entirely due to the round tables, in light of instructor reports that minimal changes were made in the syllabus and activities when courses were moved to SCALE-UP rooms.

#### *Course activities*

Overwhelmingly, students liked hands-on activities, whether it was called “laboratory,” “field trip,” “hands-on” or simply “student participation”. Students in both models reported that their classes have more student interaction than in previous science courses, that this was what they liked best about the course, and that they would add more activities of a similar nature in order to improve the course. Response rates were similar between models, except for field trips. The Environmental Biology course, which is only taught in standard model rooms, has a heavy field trip component (four to seven trips per semester) and these trips are a favorite part of the course.

General education science courses at this university are taught as combined or studio-style courses, wherein lecture and laboratory are merged in the same time frame, and cooperative learning is foundational to the mission of the institution. Courses utilizing both the standard model and the SCALE-UP model included hands-on learning in various ways. It is therefore not surprising that students in both models responded to hands-on activities in equal measure. Hands-on activities are “enactive mastery experiences” described by Bandura (1997) as necessary for development of self-efficacy. The lack of differentiation in median PTSE scores between models may be explainable by the high proportion of hands-on and group activities present in both models.

## Conclusions

This study explored the impact of the SCALE-UP teaching model on science teaching self-efficacy in general education students. Components of the model, notably inquiry/active learning and cooperative learning, have the potential to enhance science teaching self-efficacy through each of the four supports proposed by Bandura (1997): mastery learning, vicarious learning, positive reinforcement, and emotional state. Inquiry/active learning has been demonstrated to improve mastery learning (Bryant, 2006; Prince, 2004; Prince & Felder, 2007), and with it the potential for enhancing self-efficacy. Therefore a program which incorporates inquiry/active learning should enhance science teaching self-efficacy as well (Johnston, 2003). This was not found to be the case for the SCALE-UP model in this study, probably due to the use of active and cooperative learning in the standard teaching model.

Similarly, cooperative learning has the potential to improve self-efficacy through vicarious experience and positive reinforcement. Social comparison, one component of group function in cooperative learning (Bandura, 1997; Johnson & Johnson, 1994), is important to the formation of self-efficacy (Pietsch, et al., 2003). Cooperative learning should therefore foster science teaching self-efficacy, however no enhanced effect on science teaching self-efficacy was found in this study as a result of the use of the SCALE-UP model. This is likely due to the limited difference in the amount of cooperative learning between the two models.

Student responses to open-ended questions indicated that students were aware of and appreciated both active and cooperative learning in both models employed. The layout of the SCALE-UP room was perceived to be more conducive to cooperative

learning, than was the standard model, however this perception was not reflected in a difference in science teaching self-efficacy between models.

### *Summary*

Validation of the STEBI-B instrument in this study determined that science teaching self-efficacy is a valid construct in general education science students. Correlations between median PTSE scores and gender and previous science experience obtained in this study paralleled those of other authors (Joseph, 2003; Cantrell, et al., 2003; Kumar & Morris, 2005), in support of the use of this instrument and construct in this population.

At the host institution the SCALE-UP model of teaching showed no impact on general education science students' science teaching self-efficacy, as measured by the STEBI-B. This result may be attributable to several factors, alone or in combination. The SCALE-UP model encompasses several aspects, most notably room design, pedagogical approach, and classroom management. While remodeling of the rooms took place, modifications of the pedagogical approach and classroom management methods used in SCALE-UP courses may not have been implemented to the degree necessary to achieve a significant differential in PTSE score. Conversely, no loss of science teaching self-efficacy was observed as a result of delivering the standard model in the larger enrollment SCALE-UP courses.

Students reported positive experiences in both the SCALE-UP and the standard model at this institution, in the areas of group/cooperative learning and hands-on/active learning. The SCALE-UP rooms may be distracting to some students, and the larger enrollment is perceived as a detriment to student-teacher interaction. Standard model

rooms may also be distracting, but the smaller size is appreciated for the increased student-teacher interaction that is possible with smaller enrollments.

### Recommendations

The results of this research yield several directions for further study. While the STEBI-B was validated for use in this population, many of the survey items were worded specifically for teaching science in an elementary classroom setting. Modification of the instrument is warranted to reflect science knowledge and understanding sufficient to explain science at a level of science literacy, rather than to teach it in elementary school. The modified instrument will need to be validated in the general education science student population; thereafter it can be used to create benchmarks for measurement of the impact of curricular and pedagogical changes in general education science courses.

This study design measured science teaching self-efficacy at the end of the semester in multiple courses in multiple disciplines. Several disciplines and syllabi were combined within the SCALE-UP sample and within the standard (control) sample. It is possible that the lack of differentiation between median PTSE scores is due to the large diversity of disciplines/syllabi/instructors in each sample. The effect of the SCALE-UP model may be more pronounced within one discipline using a common syllabus, but taught in both models, preferably by the same instructor. In addition, pre- and post-testing in individual courses can be used to determine the effects of course syllabi/instructor on science teaching self-efficacy and the impact of any changes that are made. Faculty interviews are also recommended to elicit views on teaching philosophy, pedagogy, and experience with the SCALE-UP model.

Modifications of the pedagogy used in the SCALE-UP model at this institution are recommended in order to bring the demonstrated benefits of the model (Beichner & Saul, 2004) to bear on student populations in the SCALE-UP rooms at this institution. These modifications should focus on developing inquiry/active learning activities within a cooperative learning setting (Oliver-Hoyo, & Beichner, 2004). Only then can the impact of the SCALE-UP model on science teaching self-efficacy in general education students be truly measured.

## APPENDIX A: ASSESSMENT INSTRUMENT

## STEBI-B/modified (Bleicher, 2004)

|                              |  | yes                   | no (Do not complete the survey) |                       |                       |                       |
|------------------------------|--|-----------------------|---------------------------------|-----------------------|-----------------------|-----------------------|
| I am 18 years old, or older. |  | <input type="radio"/> | <input type="radio"/>           |                       |                       |                       |
|                              |  | strongly agree        | agree                           | undecided             | disagree              | strongly disagree     |
| 1                            | When a student does better than usual in science, it is often because the teacher exerted a little extra effort.                     | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 2                            | I will continually find better ways to teach science.  | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 3                            | Even if I try very hard, I will not teach science as well as I will most subjects.   | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 4                            | When the science grades of students improve, it is often due to their teacher having found a more effective teaching approach.       | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 5                            | I know the steps necessary to teach science concepts effectively.  | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 6                            | I will not be very effective in monitoring science experiments.  | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 7                            | If students are underachieving in science, it is most likely due to ineffective science teaching.                                    | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 8                            | I will generally teach science ineffectively.  | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 9                            | The inadequacy of a student's science background can be overcome by good teaching.   | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 10                           | The low science achievement of students cannot generally be blamed on their teachers.  | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 11                           | When a low-achieving child progresses in science, it is usually due to extra attention given by the teacher.                         | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 12                           | I understand science concepts well enough to be effective in teaching elementary science.  | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 13                           | Increased effort in science teaching produces little change in student's science achievement.  | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 14                           | The teacher is generally responsible for the achievement of students in science.   | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 15                           | Student's achievement in science is directly related to their teacher's effectiveness in science teaching.                           | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 16                           | If parents comment that their child is showing more interest in science, it is probably due to the child's teacher.                  | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 17                           | I will find it difficult to explain to students why science experiments work.  | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 18                           | I will typically be able to answer students' science questions.  | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 19                           | I wonder if I will have the necessary skills to teach science.   | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 20                           | Given a choice, I will not invite the principal to evaluate my science teaching.   | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 21                           | When a student has difficulty understanding a science concept, I will usually be at a loss as to how to help the student understand. | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 22                           | When teaching science, I will usually welcome student questions.   | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 23                           | I do not know what to do to turn students on to science.   | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |



### Demographic information:

Gender      male      female  
☐      ☐

What is your major? \_\_\_\_\_

How many previous high school courses have you had? \_\_\_\_\_

How many previous college courses have you had? \_\_\_\_\_

2 2



for office  
use only



### Additional questions:

1. How does this room compare to other science rooms you have taken courses in?
2. What are the benefits of studying science in this room?
3. What are the drawbacks of studying science in this room?
4. How do the activities in this course compare to other science courses you have taken?
5. What did you like best about this course?
6. How can this course be improved?

## APPENDIX B: INTERNAL REVIEW BOARD

### APPROVAL LETTERS



Office of Research & Commercialization

November 13, 2006

Mary Kay Cassani  
14370 Orange River Road  
Ft. Myers, FL 33905

Dear Ms. Cassani:

The University of Central Florida's Institutional Review Board (IRB) received your protocol IRB #06-3939 entitled "**The Effects of the SCALE-UP Design on Science Self-Efficacy of Non-Science Majors.**" The IRB Chair reviewed the study on 11/3/2006 and did not have any concerns with the proposed project. The Chair has indicated that under federal regulations (Category #1, research conducted in established or commonly accepted educational settings, involving normal educational practices, such as: research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods) this research is **exempt** from further review by our IRB, so an approval is not applicable and a renewal within one year is not required. The data is public information.

Please accept our best wishes for the success of your endeavors. Should you have any questions, please do not hesitate to call me at 407-823-2901.

Cordially,

  
Joanne Muratori  
(FWA00000351 Exp. 5/13/07, IRB00001138)

Copies: IRB File  
Bobby Jeanpierre, Ph.D.

JM:jm

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Academic Affairs  
Office of Research  
and Sponsored Programs

TO: Mary Kay Cassani  
College of Arts and Sciences

**Protocol ID # 2006-26**

*This Protocol ID number must be used in all communications about this project with the IRB.*

FROM: FGCU Institutional Review Board

DATE: November 9, 2006

RE: **Effects of the SCALE-UP Design on Science Self-efficacy of Non-science Majors**

Thank you for providing us with the Instructional Letter.

This project has been approved, effective November 9, 2006, as Exempt From Further Review. As long as the protocol remains unchanged, this protocol does not need Continuing Reviews.

Please remember that any changes to the protocol will require the submission of a revised protocol to the IRB. Any adverse reaction by a research subject is to be reported immediately to the Chair of the IRB through Dr. Thomas Roberts in the Office of Research and Sponsored Programs, at 239-590-7021 or via e-mail at [troberts@fgcu.edu](mailto:troberts@fgcu.edu).

Questions concerning the IRB decision or any concerns may be directed to the IRB Chair, through Dr. Roberts.

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